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ABSTRACT

Every day, school-aged children encounter a wide variety of hazards that occur both outside and inside schools. This document presents findings of a report that examined the scientific data on the risks for student injury and illness in the school environment. The information is designed to help administrators set priorities for reducing risks to students. The report focuses on the risks that students between 5 to 18 years old encounter while they are at school, on the school grounds, at school-related activities, and traveling to and from school. Key findings include: (1) The two leading causes of death in school-aged children are motor vehicles and firearms; however, relatively few of these deaths occur in schools or on school buses; (2) quite often, the relative safety of schools, on a national average basis, is unknown; and (3) schools contribute to the risks of injury or illness in school-aged children; however, little is known about schools' contribution to nonfatal illness and injury. Finally, national data, particularly for environmental hazards, were usually inadequate to assess the risks to students. Data are presented for incidence of unintentional injuries, including playground-related, school-athletics, transportation, school-bus-related, pedestrian injuries, along with data for intentional injuries, including school-associated violent deaths and weapons. Information is presented for illness caused by environmental hazards, such as asbestos and lead, and for those that arise from exposure to infectious agents. Suggestions for comparing and managing risks are offered. References accompany each chapter. Eight figures and 35 tables are included. (LMI)

Risks to Students in School

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Risks to Students in School

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Foreword

School-aged children encounter a wide variety of hazards every day. While the leading causes of mortality for this age group are hazards that typically occur outside of the school environment, many hazards resulting in injury or illness exist in schools. These hazards confront children on their way to school, in the classroom, in the use of potentially hazardous materials in science, art, and industrial arts courses, on playgrounds, in gymnasiums, on athletic fields, and on their way home.

Because of congressional interest in the health and safety of school children, the House Committee on Energy and Commerce and the House Committee on Education and Labor requested the Office of Technology Assessment (OTA) to assess the available data on hazards to children in schools in the United States. A letter of support was received from the Senate Committee on Labor and Human Resources. As directed, this study focuses on unintentional and intentional injuries (particularly violence) and illnesses from infectious diseases and environmental hazards (school materials, indoor air contaminants, and electromagnetic force).

In addition to estimating the likelihood of injuries and illnesses in schools, OTA considered the quality, relevance, and predictive value of the available data about health and safety risks by examining how the data were collected and interpreted. For many of the hazards in the school environment, the underpinning scientific research is incomplete and thus of limited use. This report does not, however, compare or rank risks. Decisionmakers, from Congress to individual school boards, are likely to want much more information than just numbers of deaths, illnesses, and injuries when setting priorities for improving school safety. Public fear of particular risks and the feasibility and cost of reducing the risk are among other very important considerations. As such, this background paper represents the first step in the process of setting priorities in risk reduction.

OTA appreciates the support this effort received from hundreds of contributors. Workshop participants, reviewers, contractors, school administrators, parents, and schoolchildren gave us invaluable support. OTA, however, remains solely responsible for the contents of this background paper.

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Summary 1

Schools, like all buildings and institutions, harbor some risks; inspection of records of illnesses and injuries in schools reveals sometimes preventable or reducible hazards. Nevertheless, compared to other places where children live and play, schools are often safer environments. This finding must be qualified by the paucity and occasional poor quality of data—or even the absence of information about some hazards. For many of the hazards that this study examined, the Office of Technology Assessment (OTA) could not judge whether schools were safer or not.

Of course, children daily confront a variety of risks, in or out of school. In 1992, children ages 5 to 17 suffered 13 million injuries and some 55 million respiratory infections, contributing to their missing about 214 million school days, roughly 460 days for every 100 students. Unknown are the possible long-term health consequences, the impact of the lost learning opportunities, or the care-giving problems faced by families. Averaged over the year, school-aged children spend about 12 percent of their time in school; some portion of their injuries and illnesses arise in connection with the school environment. Parents, teachers and school administrators, and leaders in all walks of life understand that information about the nature of risks is a basic requirement for thoughtful decisions about the interventions necessary to reduce illnesses and injuries.

Since government requires school attendance, it ultimately bears responsibility for children's health and safety while they are there. While local, county, and state governments bear most responsibility for the operation of schools, the federal government has taken a role in health and safety issues, as reflected in the 103d Congress considering 66 bills that referenced the "school environment" and 51 that were directed at the goal of "safe schools." Congressional concern led the House Education and Labor and Energy and Commerce Committees of the 103d Congress to request this background paper, which examines the scientific data on the risks for injury and illness in the school environment.[1]

[1] In the 104th Congress, the House Education and Labor Committee was renamed the Education and Opportunity Committee and the House Energy and Commerce Committee became the Commerce Committee.

SCOPE OF THE REPORT

This report focuses on risks[2] to students between 5 to 18 years old while they are at school, on the school grounds, and, to the extent possible, at school-related activities and traveling to and from school. The ages correspond to grades kindergarten through the 12th grade. About 46.5 million children were enrolled in over 109,000 elementary and secondary schools for the 1990 school year, and a projected 50 million will enroll for the fall of 1995.

Hazards are grouped according to whether they cause *injuries* or *illnesses*. For this assessment, injuries are divided into two kinds:

- those that result from unintentional actions, such as playground activities or organized sports, and
- those resulting from intentional actions, such as homicide or fighting.

Illnesses are also divided into two groups:

- those that arise from environmental hazards, such as asbestos and lead, and
- those that arise from exposure to infectious agents, such as influenza virus and respiratory-disease-causing bacteria.

This report takes one critical step—identifying and commenting on the available data—that may help in developing priorities for the use of limited resources to protect children from health and safety hazards in schools. The report does not attempt to compare and rank risks of a diverse nature; rather, the data are examined—their quality, how they were produced, the assumptions made, and their limitations. After consulting with experts in various fields, OTA staff assembled morbidity and mortality data, along with estimates and measures of exposures or risks, for events ranging from school bus crashes and other accidents to student-on-student violence, and from infectious disease outbreaks to a number of "environmental hazards," including pesticide poisoning and possible lung cancers from asbestos or radon.

Although this report does not rank risks, one section is devoted to discussing comparative risk assessment, a process favored by some to help individuals and organizations decide where resources are to be spent to reduce which risks. Beyond the traditional notions of number and severity of disease or injury, decisionmakers may want to consider other subjective attributes of risk in determining which school-related risks are most worthy of attention.

KEY FINDINGS

In examining the hazards in schools, OTA found:

Risks of Death in School

FINDING *The two leading causes of death in school-aged children are motor vehicles and firearms. Relatively few deaths from these causes occur in schools or on school buses.*

In children ages 5 to 19, motor vehicle-related injuries and injuries due to firearms dwarf all other causes of death for which data are available. In 1992, the approximately 6,720 deaths due to motor vehicle injuries and 5,260 deaths related to firearms accounted for about 50 percent of 22,600 deaths in all children ages 5 to 19 (see table 1-1). Motor vehicle-related deaths include deaths to occupants of cars or other motor vehicles involved in crashes, as well as deaths to pedestrians, bicyclists, and others injured by motor vehicles. Firearm-related deaths include deaths due to intentional injuries (i.e., firearm-related homicides and suicides) and deaths due to unintentional injuries involving firearms. In 1992, the number of intentional injuries due to firearms in school-aged children (about 3,280 firearm-related homicides and 1,430 suicides) far exceeded the number of unintentional injuries due to firearms (470 deaths).

[2] In this report, risk refers to the probabilistic estimate of the likelihood of an adverse health outcome associated with the hazard in question. Hazards are defined as the agent or action capable of causing the health effect.

TABLE 1-1: Leading Causes of Death to School-Aged Children, 1992					
Causes	**Deaths 5–9 Years**	**Deaths 10–14 Years**	**Deaths 15–19 Years**	**Deaths Total**	**Rate per 10,000**
ALL CAUSES	3,739	4,454	14,411	22,604	42.2
ALL NATURAL CAUSES	1,943	1,916	2,891	6,750	12.6
Malignant neoplasms	557	548	738	1,843	3.4
Diseases of the heart	130	154	333	617	1.2
Congenital anomalies	245	203	224	672	1.3
HIV infection	72	32	48	152	0.3
Pneumonia and influenza	53	51	85	189	0.4
Chronic obstructive pulmonary disease	38	62	90	190	0.4
ALL EXTERNAL CAUSES	1,796	2,538	11,520	15,854	29.6
All Unintentional Injuries	1,628	1,760	6,234	9,622	18.0
Motor vehicle-all	907	997	4,818	6,722	12.6
—Motor vehicle-occupant	378	481	3,269	4,128	7.7
—Motor vehicle-pedestrian	348	214	328	890	1.7
—Motor vehicle-bicycle	93	145	62	300	0.6
—Motor vehicle-other	88	157	1,159	1,404	2.6
Drowning	196	218	398	812	1.5
Fire/burn	211	105	95	411	0.8
Unintentional firearm	48	132	285	465	0.9
Poisoning	15	21	155	191	0.4
Fall	21	30	93	144	0.3
Aspiration	23	16	21	60	0.1
Suffocating	35	61	46	142	0.3
All Intentional Injuries	156	745	5,149	6,040	10.9
Suicide-all	10	304	1,847	2,151	4.0
—Firearm	3	172	1,251	1,426	2.7
—Nonfirearm	7	132	596	735	1.4
Homicide-all	146	441	3,302	3,889	7.3
—Firearm	56	348	2,878	3,282	6.1
—Nonfirearm	90	93	424	607	1.1
All Firearm	111	667	4,484	5,262	9.8
Population (000's)	18,347	18,105	17,102	53,554	

SOURCE: U.S. Department of Health and Human Services, National Center for Health Statistics, Vital Statistics System, 1995.

On the basis of national data from 1992,[3] it appears that relatively few deaths from motor vehicle-related injuries in school-aged children actually occur in school environments, defined here as school buildings and grounds and bus transportation to and from school. Except for school bus-related deaths, estimates of deaths to schoolchildren going to and from school are either unreliable or unavailable. Measured on a passenger per mile basis, the number of occupant deaths from school bus crashes is one-quarter the number from passengers of automobile crashes. Among school bus-related fatalities, children getting on or off the bus are by far at the greatest risk. In 1989, the National Academy of Sciences reported that from 1982 to 1986 an average of about 50 children died in school bus-related crashes, and roughly three-fourths of these died getting on or off a school bus.[4]

About 1 percent of the deaths from firearms in school-aged children occur in school environments. An estimated 100,000 to 135,000 guns are brought to school every day, yet children are much less likely to die from firearm-related injuries in school than out of school. During two recent school years (1992–93 and 1993–94), researchers identified an average of 53 "school-associated violent deaths"[5] per year, about 40 of which were homicides, and almost all were related to firearms. Every single killing in a school—especially the killing of a child—justifiably receives considerable public attention. The fact is, however, that school-associated violent deaths constitute only a tiny portion of the several thousand violent deaths among school-aged children each year.

Most of the deaths from motor vehicle and firearm injuries are concentrated among older teenagers. No health hazard for any age group examined in this report compares in magnitude to the impact of deaths resulting from motor vehicle injuries and firearm use in 15- to 19-year-olds. Combined motor vehicle and firearm-injury-related deaths among this group represent about 40 percent of deaths among *all* school-aged children. Among younger school-aged children (ages 5 to 9 and ages 10 to 14), motor vehicle- and firearm-related deaths are a smaller proportion of total deaths. In these children, deaths from natural causes—i.e., acute and chronic illnesses—exceed deaths from motor vehicle injuries or firearm-related injuries and are roughly equal to deaths from all injuries.

FINDING *There are many other less common causes of death among school-aged children. For these, schools sometimes pose a greater risk than other environments, sometimes about the same risk, and sometimes less. Quite often, the relative safety of schools, on a national average basis, is unknown.*

Less common causes of death among school-aged children include infectious and other diseases (e.g., cancer), congenital anomalies, unintentional injuries other than firearms or motor vehicles (e.g., drowning, fires, poisoning, falls), and nonfirearm-related suicide and homicide (see table 1-1). In the school environment, these hazards do not appear to account for more than 10 to 100 deaths per type of hazard annually. Childhood exposure to environmental hazards such as radon and asbestos in schools and other environments may cause some deaths later in life, in contrast to deaths from many injuries, such as homicides, for which death is more immediate.

Schools probably pose a greater risk to children than out-of-school environments for deaths from infectious diseases. There is no certainty

[3] OTA's findings with respect to risks to students in schools are based on national averages. OTA did not make any attempt to compare regions, districts, or individual schools that may be better or worse than average.

[4] The most recently published National Highway Transportation Safety Administration's school bus crash-related fatality estimates are available in *Traffic Safety Facts*, 1992; except for pedestrians, the data are not published by age so the number of school-aged children fatally injured is not known.

[5] The Centers for Disease Control and Prevention includes homicides, suicides, and unintentional firearm fatalities in "school-associated violent deaths" (12).

that this is true because a school's contribution to disease is rarely determined. But school environments are probably incubators for fatal infections that can be spread through casual contact in classrooms. In 1992, about 190 school-aged children died from pneumonia and influenza, two respiratory infections that can be spread via casual contact in classrooms. In the same year, 150 school-aged children died from infection with human immunodeficiency virus (HIV), the virus that causes AIDS. HIV is spread through the exchange of bodily fluids (blood or semen) during sexual activity or intravenous drug use. Currently, there is insufficient information to evaluate the importance of school contacts in the transmission of HIV.

Deaths from cancer that might be related to in-school exposures to environmental hazards may not occur for many years after the exposure, and in-school exposure data, if they exist at all, are usually inadequate to estimate the risks for developing and dying from cancer. The concentrations of both radon and asbestos in school buildings are about the same as concentrations found in other buildings. Using U.S. Environmental Protection Agency (EPA) estimates of the cancer-causing potential of asbestos, this study extrapolates that for a given school year, average in-school exposures to asbestos may ultimately result in 2 to 60 lung cancer deaths. Similarly, extrapolating from EPA estimates of the cancer-causing potential of radon, average per year in-school exposures to radon may lead to about 60 lung cancer deaths above and beyond those associated with contributions from other sources of radon.

There is considerable uncertainty associated with both of these extrapolations, however, and the actual numbers of deaths associated with in-school exposures to asbestos or radon may be higher than estimated—or zero. There is even more uncertainty associated with estimates of cancer deaths due to exposures to electromagnetic fields (EMF), because the biological effects of electromagnetic fields are not well understood and too few data exist on in-school exposures and their possible impact.

Clearly, schools can contribute to exposures to environmental hazards. While the school environment's contribution to overall risk can sometimes be calculated, though, it must be remembered that other environments—notably, the home—might expose children to these hazards as much or more.

The relative risk to school-aged children of deaths in schools from most unintentional injuries not due to firearms or motor vehicles is not known. For example, it is known that about 20 high school students die in school athletics, but it is difficult to judge whether these activities in schools are safer or riskier than similar ones out of school, because comparable out-of-school data are unavailable for the same activities.

Risks of Injury or Illness in School

FINDING *Schools contribute to the risks of injury or illness in school-aged children. Once again, schools sometimes pose a greater risk than other environments, sometimes about the same risk, and sometimes less. But little is known about schools' contribution to nonfatal illness and injury.*

Data on the incidence of injury or illness in school-aged children—i.e., on the number of new cases of injury and illness in this population in a given time period—are available from the Centers for Disease Control and Prevention. An important measure of the impact of injuries and illnesses on students is the number of school days lost because of an injury or illness. In 1992, illness accounted for approximately 75 percent of the nearly 175 million lost school days from short-term conditions (both injuries and illness). Illnesses were responsible for more lost school days than were injuries (even though injuries resulted in more fatalities than illnesses did).

For most of the hazards related to the incidence of injury and illness in school-aged children, OTA found that the data were inadequate to allow in-school and out-of-school comparisons. While for certain hazards the relative risk is not known because too little information exists, for others the relative risk cannot be determined because the nature of the hazard's effect on children's health precludes the possibility of linkage to a school location. Athletic injuries, for example, are reasonably well documented in school, but the out-of-school data are not particularly useful for comparisons due to inadequate data on location or their single-sport focus. Other risks (e.g., fighting) are difficult to determine because of inadequate reporting on the cause of the injury.

For a few sources of injury and illness, it appears that schools pose a risk greater than that posed by out-of-school environments. Thus, for example, schools may facilitate the spread of infectious diseases, especially of highly infectious diseases such as viral respiratory diseases. Certain disease outbreaks, such as meningococcal infections and food poisonings, can be traced to the school environment. Furthermore, conditions at certain schools exacerbate exposures to substances such as lead. The largest source of exposure to lead comes from younger children eating paint chips at home, but some schools may add to this exposure through the presence of lead in building paint and in water.

For other sources of injury and illness, it appears that schools pose a risk comparable to that posed by out-of-school environments. In the case of elementary school children, for example, about as many injuries occur on school playgrounds during school hours (9 a.m. to 3:30 p.m.) as occur in other locations. Athletic injuries are among the most common causes of school injuries to older students; the few available studies indicate that they occur at similar rates inside and outside of school.

For many sources of injury and illness, schools actually pose less of a risk than out-of-school environments. Thus, for example, schools pose less of a risk than out-of-school environments for many environmental hazards. At most about 7 to 8 percent of reported exposures to poisons among school-aged children occurred in schools. Furthermore, according to a 1989 study,[6] fewer injuries requiring hospitalizations occurred in school than out of school. Moreover, in another study,[7] about 3 percent of injuries presented to the national trauma database were school related. Similarly, school bus crashes did not result in nearly as many injuries as crashes of other motor vehicles. Schools were also less of a risk for violent injuries.

The Risk Assessment Process

FINDING *For many of the risks OTA reviewed, national data were usually inadequate for an assessment of risks in schools. The largest data gaps existed for environmental hazards.*

In addition to estimating the likelihood of injuries and illnesses in schools, OTA considered the quality, relevance, and predictive value of the available data by examining how the data were collected and interpreted. For many of the hazards in the school environment, the underpinning scientific research is incomplete and thus of limited use.

OTA identified several obstacles to the collection of more complete information on the hazards facing children in schools. One obstacle is a lack of resources, whether money, expertise, or both. Another type of obstacle is resistance to data collection on the part of school administrators, perhaps out of fear of being branded a "problem school." Furthermore, epidemiological studies seldom focused on school health and safety risks, and few surveillance systems at the Centers for Disease Control and Prevention and state programs monitored injury or illness in school. The lack of both standardized federal and state definitions for reporting hazards, injuries, and illnesses, and of coordinated reporting efforts over time also impedes accurate portrayal of school injuries and illnesses. With respect to unintentional injury data, for example, there are inconsistent definitions of reportable injuries and designations of severity.

[6] Injury data compiled by the Massachusetts Statewide Comprehensive Injury Program (8).
[7] Data from this study were compiled from September 1979 and August 1982.

The largest data gaps existed for environmental hazards such as radon, asbestos, and EMF. OTA generally did not find comprehensive data on in-school exposures to these types of substances. For most of these agents, the simple presence of a hazard—not the level to which students are exposed—is reported. With few exceptions, efforts to obtain exposure data have been sporadic, and reporting has been anecdotal. The absence of studies documenting exposure in school presents a fundamental gap in the data needed to assess risks nationwide. Because of those gaps, officials and investigators may never link certain observed health effects to exposure to the culpable agent in the school environment.

Unlike injuries or illnesses from environmental hazards, cases of specific infectious diseases must be reported to the Centers for Disease Control and Prevention, but records do not necessarily identify schools as the location of the culpable exposure. For infectious diseases, data are usually reported for school-aged children, but only certain cases of school outbreaks, e.g., meningococcal infections or food poisoning, accurately establish schools as the source of the illness.

FINDING *Decisionmakers, from Congress to individual school boards, are likely to want much more information than just numbers of deaths, illnesses, and injuries when setting priorities for improving school safety. Public fear of particular risks and the feasibility and cost of reducing the risks are among other very important considerations.*

Clearly, 20 deaths from one in-school hazard are worse than 10 deaths from another, but does that information tell us which problem to address first or on which to spend the most money? People naturally tend to order things by their size or severity, and quantitative estimates of the magnitude of risk—i.e., the likelihood of adverse health effects arising from the hazardous conditions—are useful in setting priorities. The magnitude of risk can be quantified in any of several ways (e.g., using measures of the individual probability of risk, the risk to the population, or weighting the risk by age, accounting for the additional years of life lost for the child), each measure stressing a different aspect of the risk.

But quantitative estimates of the likelihood of adverse health effects arising from particular hazards are not all that are needed for local school boards and other decisionmakers to determine what can and should be done to make schools safer. Decisionmakers may want to take into account the social context of the risk.

One aspect of the social context that is particularly important is the degree of public fear associated with a risk. The level of fear of a given hazard varies widely across individuals and communities. One thing that sometimes determines the level of fear is the degree to which individuals feel that they are able to control the risk through personal action. Thus, even though the risk may not be very great, parents may fear their child being killed in school by another student with a weapon because they cannot control the risk; at the same time, parents may have less fear of a comparable risk—that their child will die en route to and from school in a bus crash—because they feel that they can control this; they can drive the student themselves or arrange alternative travel.

Another aspect of social context is the perception that a given hazard—say, playing football—has benefits that make the associated risks more worth taking or bearing. In terms of the number and severity of associated injuries, football is among the most hazardous of athletic activities in which high school students participate. Nonetheless, the perceived benefits of athletic accomplishment and social recognition encourage continued participation in this activity.

Local school boards and other decisionmakers seeking to determine what can and should be done to make schools safer need to take into account the feasibility and cost of reducing different risks. School boards must decide, in some cases, if the risks of firearms and firearm-related injuries in their schools justify the substantial costs of metal detectors. Small risks that are cheap and easy to eliminate may deserve priority attention, whereas even very large risks may not emerge as priorities if reducing them would be technically infeasible or prohibitively expensive.

The remainder of this chapter summarizes the findings and conclusions from the subsequent chapters of this report. The next section covers student injuries, both intentional and unintentional. The illness section examines illnesses arising from environmental hazards and infectious diseases. Finally, the last section looks at how the presented data can be used by decision-makers and those interested in the safety and health of students in school.

INJURY TO STUDENTS IN SCHOOL

This report examined school injuries in terms of "intent"—unintentional (accidental) and intentional (assaultive or suicidal). Unintentional and intentional injuries differ in the type of injury that results, its severity, the manner in which it is recorded at schools, and the level of response or fear it engenders. The types and quality of data collected for unintentional and intentional injuries also vary. While some national and state estimates of school injuries are available, epidemiological studies provide a more detailed picture of injury incidence. In this section, we draw together available school injury data from both types of injury.

In 1992, school-aged children in the United States incurred over 13 million injuries (1).[8] Results of epidemiological studies indicate that from 10 to 25 percent of injuries incurred by the school-aged population occur at school (29). However, epidemiological studies use a broader definition of injury than the national survey. Regardless of the number of injuries, over 10 million school days are lost each year—22 lost school days per 100 students (1). Since 12 percent of a child's year and 15 to 20 percent of a child's annual waking hours are spent in school, the frequency of injury per hour in school or out is about the same. However, most of these injuries are minor. The more severe injuries tend to occur out of school. For certain types of injuries, such as athletic injuries, the percentage of injuries incurred in schools may be higher than outside the school environment; however, for other injuries, particularly fatal injuries such as homicide, it is considerably lower: 1 percent of deaths due to violence for children 5 to 18 occur at schools.

The leading causes of death to children of school age (5 to 19 years) are motor vehicle crashes and injuries, intentional or unintentional, associated with firearms. In 1992, about 6,720 deaths due to motor vehicle injuries and the 5,260 deaths related to firearms accounted for approximately 50 percent of 22,600 deaths in the more than 53 million school-aged children, dwarfing all other causes of death for which data are available. Motor vehicle injury deaths include deaths to occupants, pedestrians, bicyclists, and others injured in automobile crashes. Firearm-related deaths include firearm-related homicides and suicides as well as unintentional firearm injuries.

Unintentional Injury

Given the time students spend at school and the variety of activities in which they are engaged, the school environment presents many opportunities for unintentional injury. Risks of unintentional injury to students occur each school day: in their travel to school; in the controlled, supervised classroom environment; in physical activities in gymnasiums and athletic fields; in the relatively unsupervised play during recess and lunch periods; and finally, on their return home (28). Although many of these injuries are minor cuts and bruises that heal quickly, significant numbers are quite serious. The injuries may result in absence from school, restricted activity, hospitalization, disability, and even death.

[8] This estimate includes only those injuries involving medical attendance and at least half a day of restricted activity.

Incidence and Distribution of School-Related Injuries

Injury rates from school-related injury studies vary and are likely to underrepresent the number of actual injuries because of underreporting in the routine surveillance and reporting of injuries at schools (9). The variations may be attributed to one or more of the following: 1) varying case definitions of injury; 2) reporting methods that vary (e.g., school-based as opposed to hospital-based reporting); 3) inconsistent reporting among study schools; 4) variability among student populations; and 5) implementation of school-based prevention programs.

Population-based estimates of rates of injury to school-aged children range from about 24 to 28.6 injuries per 100 school-aged children in 1992 (1,8,29,30). As shown in table 1-2, the rates of injury in school estimated in several epidemiologic studies range from 1.7 to 9.2 per 100 students. Based on 1988 NHIS data, one study found that 19 percent of all injuries sustained by children under 17 occurred at school (30). Considering the shorter time spent in school each year—about 12 percent of a child's time annually—the data thus suggest that the number of school injuries may be about the same or higher than those out of school.

Playgrounds and athletics (including both physical education and organized sports) account for the highest injury rates in school. Distribution of these injuries, however, changes over time due to students' development of physical skill, strength, size, judgment, balance, and experience with hazards (28). Playgrounds are associated with most injuries to elementary students and athletic injuries account for the most injuries to secondary school students. The rates of playground injuries decrease as children mature, while the rates of athletic injuries increase steadily through middle/junior high school to high school.

The majority of school-related injuries are minor; they also result in fewer hospitalizations than injuries sustained outside the school environment, and fatal injuries are relatively rare in the school environment (28). The percentage of severe injuries—ranging from 18 to 39 percent of the total injuries across three epidemiological studies (two Canadian studies and one United States study)—varies because, among other things, severity is defined differently from study to study. Playground and sports athletic injuries account not only for the greatest number of injuries but also for the majority of severe injuries (2,14,32). Falls (either from the same surface or from elevation), organized sports or athletics, and unorganized play were the activities most frequently associated with injuries (9). Compared to outside of school, in-school injuries were less severe.

Playground-Related Injury Data

The 1990 Consumer Product Safety Commission (CPSC) *Playground Equipment-Related Injuries and Deaths* report (36) provides an analysis of data on playground injuries and deaths associated with playground equipment.[9] Fatalities averaged nine per year for children under 15 years of age, with about 170,200 playground equipment-related injuries in 1988.[10] Using these data, OTA estimated that approximately 13,000 playground equipment-related injuries occurred on school playgrounds, during school hours,[11] to school-aged children. The 1992 CPSC estimates 241,181 playground equipment injuries required treatment in hospital emergency rooms.[12] Poor out-of-school data on playground-equipment injuries prevent comparison with the in-school data.

[9] The CPSC data includes only fatalities and injuries that are product-related and, accordingly, exclude those that occur on playgrounds but are not equipment related. Moreover, CPSC collects only emergency room data and, thus, only the most serious injuries.

[10] From April to December 1988, CPSC completed a special study of a systematically selected sample of playground injury incidents to follow up in depth. The study identified out-of-scope cases, meaning cases involving injuries that were not associated with outdoor playground equipment. Extrapolating the percentage of out-of-scope cases to the 1988 NEISS, CPSC determined that the estimated 201,400 emergency room-treated playground equipment-related injuries should be reduced to 170,200.

[11] School hours are defined as 9:00 a.m. to 3:30 p.m.

[12] CPSC has not adjusted these numbers.

TABLE 1-2: School Injury Epidemiological Studies

	Lenaway et al. (1992)	Boyce et al. (1984a)	Sheps & Evans (1987)	Feldman et al. (1983)	Taketa (1984)
Years analyzed	1988-1989	1980-1983	1981-1983	1981-1982	1981-1982
Site	Boulder, CO	Tucson, AR	Vancouver, BC	Hamilton, Wentworth, Ont.	Hawaii
No. of schools	9	96	108	212	204
Grades	K–12	K–12	K–12	K–13	K–12
Student population	5,518	55,000	53,000	83,692	157,000
Data collection	Prospective	Prospective	Retrospective	Prospective	Retrospective
Definition: reportable injury	Student accident report forms completed by adult administering first aid (i.e., teacher, nurse, or coach). Reportable injuries were those: "requiring medical or dental attention, head injuries necessitating student dismissal to home and those with persistent symptoms beyond a two hour observation period, poisoning, suspected fractures, human bites, puncture wounds, and injuries sustained from fighting or equipment failure"	Must meet one of the following criteria: (1) required a physician's care and/or major first aid, (2) resulted in an absence from school, or (3) resulted in restricted participation in competitive sports	If a child sustains or requires: "all head injuries, suspected or definite fractures, and ambulance or inhaler, referral to a physician or dentist, sutures or a foreign body in the eye"	Decision as to reportability "made by school principal, consistent with his interpretation of the school board's policy"	"Any accident which happens at school, or at a school sponsored activity, on or off campus, which (1) interrupts the students' normal or expected activity for that period to any significant degree, (2) causes any property damages or losses of more than $5 in estimated replacement cost and/or (3) can generate a litigation on behalf of the injured"
Incidence per 100 student years	9.22	4.9	2.82	5.4	1.7
Definition: severe injury	*	Amputations, third degree burns, concussions, crush wounds, fractures, multiple injuries	Fractures, loss of consciousness, burns, whiplash, open wounds, foreign body in eye	Fractures, loss of consciousness, dislocations, sprains, torn ligaments and cartilage, chipped/broken teeth, internal injury	"Most severe...foreign bodies in the eye and fractures"
Percentage of injuries that were serious or severe	*	18%	35% elementary 39% secondary	28.6%	

* no definition of severe or serious

SOURCES: Office of Technology Assessment, 1995, Adapted from R.R. Gratz and K. Finison, "School Injuries: What We Know, What We Need," *Pediatric Health Care* 6:256-262, 1992; D.D. Lenaway, et al., "The Epidemiology of School Related Injuries: New Perspectives," *Am J Prev Med* 8(3):193-198, 1992.

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School Athletic Injury Data

In 1993, approximately 5.6 million students competed in high school athletics (22), comprising approximately 43 percent of all United States high school students (37). Student participation in athletic activities is a principal cause of junior high and high school injuries and results in a number of debilitating injuries and deaths each school year.

The only national school sports injury mortality figures are compiled by the National Center for Catastrophic Sports Injuries Research. The Center limits its research to certain high school and college sports, and does not include physical education. Over the 10 years of study, 200 deaths were reported (67 direct and 133 indirect),[13] an average of approximately 20 sports-related deaths annually (see table 1-3). Of all the direct deaths in high school sports, only one was a female (21).

Football and soccer resulted in the greatest number of direct deaths each year among high school athletes. On average, of the 20 athletic related deaths each year, about five directly related deaths occur in football and about five in soccer. Football is associated with about five indirectly related deaths per year and basketball with three to four. While those three sports account for more than 90 percent of the fatalities, they are not necessarily the riskiest when judged by number of deaths per participant in a sport per year. In those terms, the riskiest high school sports for males were gymnastics (1.75 deaths per 10,000 participants), lacrosse (0.57), ice hockey (0.43), and football (0.35). Basketball (0.63), lacrosse (0.57), ice hockey (0.43), and wrestling (0.41) had the highest rate of indirect deaths per participant.

TABLE 1-3: Reported Catastrophic Injuries from High School Sports, 1982 to 1992

	Fatal		Nonfatal			Rate/100,000 Participant Years	
Sport	**Direct**	**Indirect**	**Permanent**	**Serious**	**Total**	**Male**	**Female**
Cross country	0	5	1	0	6	0.6	0.0
Football	48	52	103	113	316	2.4	—
Soccer	2	8	0	4	14	0.5	0.2
Basketball	0	35	2	2	39	0.6	0.1
Gymnastics	1	0	5	3	9	4.8	2.3
Ice hockey	1	1	4	2	8	3.6	—
Swimming	0	3	4	3	10	0.6	0.6
Wrestling	2	10	16	9	37	1.5	—
Baseball	3	5	7	6	21	0.5	—
Lacrosse	1	1	0	0	2	1.0	—
Track	9	12	6	6	33	0.6	0.0
Tennis	0	1	0	0	1	0.1	0.0
Total	**67**	**128**	**148**	**148**	**491**	**16.8**	**3.2**

SOURCE: F.O. Mueller, C.S. Blyth, and R.C. Cantue, Tenth Annual Report of the National Center for Catastrophic Sports Injury Research, Fall 1982–Spring 1992. Chapel Hill: University of North Carolina, 1993.

[13] The Center categorizes injuries as direct or indirect—direct meaning those injuries that resulted from participation in the skills of the sport; indirect meaning those injuries that were caused by systemic failure as a result of exertion while participating in a sport activation or by a complication that was secondary to a nonfatal injury.

For national school sports, including both organized sports and physical education, morbidity estimates disclose that sports account for the greatest number of injuries in school. Of the 1.3 million sports/recreation injuries sustained by children ages 17 and under annually, schools are the location for 55 percent (715,000 injuries) and the cause of 35 percent (455,000 injuries) (30). Another school sports injury study—based on a 1986 injury surveillance study by the National Athletics Trainers Association—estimated 1.3 million injuries annually. Epidemiological studies show that sports-related injuries account for 23 to 53 percent of all reported school injuries. Physical education classes account for a greater number of injuries than organized school sport (13). Injuries sustained in physical education occurred mainly during gym games (e.g., dodge ball and four square) and basketball, with other sports far behind. About 60 percent of the basketball injuries occurred during physical education (45). However, once participation ratios are considered, organized sports (12 injuries/100 students) are riskier than physical education (2.3/100).

Transportation Injury Data

Children and adolescents travel to and from school by school bus or car, ride their bicycles, or walk. The only travel mode for which detailed injury data exists is by school bus. Though information would be useful regarding injuries from other modes of transportation to school, particularly parents' driving students or older students driving themselves, no studies attempt to quantify these injuries for students.

The few studies that report injuries incurred on the journey to and from school estimate the range from 1 to 3 percent of all school injuries.[14] In general, the journey home is more dangerous than the trip to school (37,42). One study attributed this to more children walking home alone or with other children rather than with an adult (37).

School Bus-Related Crashes

Every school day, school buses transport about 25 million students to and from classes and school-sponsored activities (23). Although most crashes involving school buses are minor, catastrophic crashes resulting in student fatalities and serious injuries occur every year. A comparison of school bus-related crash and passenger car crash fatalities and injuries among school-aged children suggests that school buses are much safer than the other forms of transportation that take students to and from school. The National Academy of Sciences (NAS) estimates that occupant fatalities per mile for school buses are approximately one-fourth those for passenger cars (23).[15] Of the more than 650,000 fatal traffic crashes in the past 16 years, less than 0.4 percent were classified as school bus related (41).

The major studies of fatalities in school bus-related crashes are listed in table 1-4. The NAS study reports that on average school bus-related crashes fatally injured about 50 school-aged children each year from 1982 to 1986. Most of the fatal injuries among school-aged children occur while they are getting on or off, rather than while they are riding, the school bus. It also appears that student pedestrians are at a far greater risk of being killed by the bus they were on—usually in the school bus loading zone—than by another vehicle (42).

[14] These estimates are based on the Hawaii Department of Education and Utah Department of Health state estimates of school injuries and the National Safety Council's national estimates. The NSC reported that about 3.1 percent of all school injuries were incurred going to and from school, 1.9 percent were motor vehicle related, and 1.2 percent were non-motor vehicle related. Because these injuries were reported to the NSC by schools, it is likely that a number of transportation injuries occurred but were not reported to the school.

[15] According to the National Safety Council's (25) *Accident Facts* (1993), the difference between school bus and passenger car fatality rates was even more pronounced. NSC reported that in 1989–91 the average fatality rate per hundred million passenger miles was 0.02 for school buses and 1.05 for passenger cars.

TABLE 1-4: Annual Passenger, Pedestrian, and Bicyclist Fatalities in School Bus-Related Crashes, by Study

STUDY	Annual Total Number of Fatally Injured People in School Bus-Related Crashes	School-Aged School Bus (or Vehicle Used as School Bus) Passengers Fatally Injured	School-Aged Pedestrians Fatally Injured	School-Aged Bicyclists Fatally Injured
1992 NHTSA's Traffic Safety Facts (FARS)	124	9	29	2
1983–1992 NHTSA's Traffic Safety Facts (FARS)	157		30	
1977–1990 Summary of Selected School Bus Crash Statistics (FARS) (average)	179	11–12	34	
1982–1988 NAS Report on Improving School Bus Safety (FARS) (average)	149	12	37–38	3.2
1991–1992 National Safety Council	110	10	25	

SOURCES: U.S. Department of Transportation, National Highway Traffic Safety Administration. *Traffic Safety Facts 1992*, September 1993; U.S. Department of Transportation, National Transportation Safety Board, *Summary of Selected School Bus Crash Statistics in 1990*, 1993; National Research Council, Transportation Research Board, Committee to Identify Measures That May Improve the Safety of School Bus Transportation, *Improving School Bus Safety* (Washington, DC: National Academy Press, 1989); National Safety Council, *Accident Facts* (Itasca, IL: 1993).

NAS developed a school bus-related nonfatal injury estimate using selected state data. School bus-related crash data from 14 states were aggregated and analyzed to develop a national estimate of 19,000 total injuries, 9,500 of which were to school bus passengers. The report concluded that school bus passengers sustained 50 percent of the total injuries, of which 5 percent were incapacitating.[16] The majority of the school bus-related crashes were minor. About 800 injuries suffered by school-aged pedestrians in school bus-related crashes were reported; of those, 35 percent were injured by being struck by school buses and the remaining 65 percent were struck by other vehicles. In contrast to fatality estimates, far fewer pedestrians than school bus passengers were injured, but pedestrian injuries were typically more severe.

Pedestrian Injury Data

Fatalities and injuries occur to student pedestrians while walking to and from school. NHTSA collects school-aged pedestrian mortality and morbidity data, but the information does not indicate if the travel was school related. However, databases that record pedestrian injuries by age and time provide some estimates to indicate the scope of the problem. At OTA's request, NHTSA generated time of day data for school-aged pedestrians and bicyclists using 1992 FARS and GES data. Assuming students typically travel to school between the hours of 6:00 and 9:00 a.m. and travel home between 2:00 and 5:00 p.m., 121 school-aged pedestrians were fatally injured; an additional 9,600 suffered nonfatal injuries. Thus, for each death of a school-aged pedestrian during these hours, there were about

[16] Incapacitating injury is defined as "any injury that prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred" (23). It includes, but is not limited to, severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, being unconscious at or when taken from the accident scene, and being unable to leave the accident scene without assistance (23).

80 injuries. Twice as many fatalities and injuries occurred in the afternoon as in the morning.

Intentional Injury

Even though the media, parents, students, law enforcement officials, and many other observers have taken it as axiomatic that school violence has increased during the past few years, no comprehensive national surveillance system tracks injuries from intentional violence in the school environment. Many researchers and analysts believe that characterizing physical—and to a lesser extent, verbal and psychological—assaults is a required step in understanding school violence. The National School Boards Association estimates that assaults rank at the top of a list of more than 16,000 violent incidents reported on a daily basis in school buildings (26). Seventy-eight percent of the more than 2,000 school districts reporting to the National School Boards Association survey about violence noted that they have had problems with student-on-student assaults during the past year. This response came from 91 percent of urban districts, 81 percent of suburban districts, and 69 percent of rural districts.

School-Associated Violent Deaths

Homicide and suicide are ever-present threats for children of school age. All killings, especially of children, occurring in school justifiably receive considerable public attention. Yet the 53 "school-associated violent deaths"[17] in 1992 constitute a small fraction of the relative mortality of the school-age population, with the 3,889 homicides and 2,151 suicides occurring outside of school in children ages 5–19 years (34). Currently, the National School Safety Center (NSSC) is the only comprehensive source of information on these incidents in schools, which it compiles from analysis of newspaper clippings.

Preliminary data from a recent Centers for Disease Control and Prevention (CDC) analysis of the NSSC data over a **two-year period** show that 105 violent deaths occurred on school campuses from 1992 through 1994. Of these, 87 were homicides, 18 were suicides, and five were ruled "unintentional" through the legal process (12).

Suicide, the eighth leading cause of death in the United States, is the third leading cause of death for young people 10 to 19 years old (38). Between 1970 and 1984, suicides in this group rose 55.2 percent. Though school does not appear to be a prominent site for the commission of suicide, parents, students, staff, school health officials, and researchers interviewed by OTA stated that depression and general emotional highs and lows are frequently part of the school and adolescent experience.

Weapon Carrying

After motor vehicle injury-related deaths, firearm-related incidents are the next leading cause of death for children ages 5–19 years. In 1992, firearms accounted for 5,262 deaths—about 10 per 10,000 children of school age. Of these, 3,282 were homicides, 1,426 suicides, and 465 were unintentional firearm-related deaths. Moreover, the firearm-related deaths in 1992 account for 23 percent of all deaths, the second leading cause of death for school-aged children (table 1-1). Deaths from firearms occur predominantly in the young adult age group, ages 15 to 19, accounting for nearly 31 percent of all deaths in this population. However, less than 1 percent of these deaths occur from shootings in school.

Estimates of the number of weapons in school vary widely (box 1-A). According to the National School Boards Association and the Center to Prevent Handgun Violence, anywhere from 100,000 to 135,000 guns are brought into schools every day (4, 26). In Cleveland, 22 percent of boys in a sample of 5th, 7th, and 9th graders reported owning a gun to protect themselves

[17] NSSC and the CDC define "school-associated violent death" as any homicide, suicide, or weapons-related death in the United States in which the fatal injury occurred on the school grounds, or at or on the way to an official school-sponsored event.

BOX 1-A: Weapons Confiscated on School Campuses

Weapons possession is tracked differently in school systems that keep such statistics. This area is rife with definitional problems, because many school districts report incidents but not necessarily the type of weapon involved. It is often impossible to discern from local school board incident reports whether a gun, knife, club, or other weapon precipitated disciplinary action against a student.

Characterization of the seriousness of weapons in schools, however, varies from location to location. In some areas, such as South Carolina, the Department of Education reported that possession of weapons was the most frequently occurring offense. For other school districts, including New York City, Los Angeles Unified, and most Connecticut districts, weapons offenses—although not the number one offense—rank high on school crime lists, preceded by vandalism, assault, harassment, larceny, and burglary, many of which involved weapons possession as a secondary offense.

The difficulty in tracking weapons possession in schools stems primarily from the fact that many school districts report the most serious offense as the primary incident. Therefore, weapons are ignored as a secondary offense and consequently are not often reported in school incident data. In South Carolina, for example, from June 1992 through May 1993, weapons possession as the most serious offense accounted for 21 percent (626 incidents) of all incidents. However, the total number of incidents involving weapons was 36 percent (1,055) of all school incidents reported in South Carolina during the 1992–93 school year. Other schools districts, such as Los Angeles Unified School District, further classify weapons incidents to distinguish between assaults and possessions and also to determine at what level (whether elementary, junior high school, or senior high school) such incidents are occurring. Still, the newness of mandatory school crime reporting legislation in South Carolina and other areas means that good baselines are in the process of being created to measure trends in these offenses and incidents.

Although the diversity in mechanisms and definitions used to collect statistics on weapons possession has made it impossible to generalize trends outside a given school district or state, most school districts reporting to OTA stressed that knives and other sharp objects, such as "box cutters," are the most commonly employed or confiscated weapons. Perhaps this is due to the accessibility and low cost of knives. In the 1992–93 school year, South Carolina's Department of Education reported that approximately 42 percent of weapons incidents involved knives or sharp objects. Handguns and other firearms are usually the second most popular choice of weapons among students in California, Connecticut, and New York, where more comprehensive statistics have been kept.

SOURCE: Office of Technology Assessment, 1995.

from threats and insults (31). New York City school security officials told OTA that they had confiscated 65 guns from students on school grounds barely four months into the 1993–94 academic school year (35). The State of Florida has admitted similar problems, with a 61 percent increase in handguns between the 1986–87 and 1987–88 school years (4).

With recent shootings in many urban, rural, and suburban communities, concerns about weapons in schools will probably remain a top priority for local school boards. A number of shootings have drawn attention to the problem of guns in school, but it is important to note that knives and razors are the weapons most likely to be found on students in the schools sampled by the Youth Risk Behavior Surveillance System (YRBS) (13). Findings from the CDC also identify a fundamental fact related to the demography of violence in schools: access to weapons and assaults occurs across a spectrum of social groups and in many geographic areas. It is not confined to particular social groups or urban schools.

Physical Fighting

Data on the prevalence and severity of physical fighting among school-aged youth have emerged from recent national and local surveys. A 1990 questionnaire from the YRBS[18] at the CDC (13) asked students, "During the past 30 days, how many times have you been in a physical fight in which you were injured and had to be treated by a doctor or nurse?" Approximately 8 percent of those students reported having been in at least one fight in which they were injured and required medical attention during the previous month. Among students who fought, 53 percent indicated that they had fought one time, while 28 percent of respondents indicated that they had fought two or three times, and 10 percent stated that they fought at least four times.

The preponderance of research about physical fighting has revealed gangs as a leading factor in interpersonal violence in some schools (3,11). According to the northern California-based Center for Safe Schools and Communities, "youth gangs of all races have increased by 200 percent in the last five years and female gangs now represent 10 percent of all gang groups in the nation" (5).

SCHOOL ILLNESS

In 1992, school-aged children missed approximately 154 million school days, 285 days for every 100 students, from illnesses associated with acute respiratory and digestive conditions and infectious diseases alone (1). These illnesses account for about 75 percent of the nearly 175 million lost school days from short-term conditions (both injuries and illness). Although illnesses account for fewer fatalities than injuries in this age group, three illnesses are among the leading causes of death: cancers, congenital anomalies, and heart disease. About 3,130 school-aged children died from these diseases in 1992, but these deaths are not likely to be school related. The leading causes of death from environmental hazards and infectious disease include fatal poisonings, which claimed the lives of 191 children in 1992; the respiratory diseases pneumonia and influenza, which led to 189 deaths; and infection with the human immunodeficiency virus (HIV), which contributed to the deaths of 152.

This report splits health hazards leading to illness between environmental hazards and infectious disease hazards. OTA groups these hazards into four categories, originating from: 1) school materials, 2) indoor air contaminants, 3) school location, and 4) infectious diseases. These categories depend most heavily on the source of exposure, which to a large extent determines the route of exposure—whether the agent is inhaled, absorbed through the skin, or ingested—and the possible health effects (see table 1-5). Such a categorization is useful for removing the focus of attention away from particular hazards and toward finding common strategies for preventing or reducing threats to health from hazards in each category.

Three types of information are needed to associate an agent found in the school environment with illness. First, there must be evidence that exposure to the agent can produce the observed symptoms. Second, there must be evidence that the student was exposed to the agent in the school environment. When these two conditions are met, there remains the task of showing it was the in-school exposure and not an exposure elsewhere that caused the disease.

Materials in the School Environment

Some hazardous school materials are intentionally brought to the school environment for use in the classroom, (e.g., art supplies, chemicals used in science courses) and for maintenance and cleaning of the school building and school grounds (e.g., solvents and pesticides). School officials and public health professionals have identified specific school materials that pose

[18] The findings covered 11,631 9th through 10th grade students in the 50 states as well as the District of Columbia, Puerto Rico, and the Virgin Islands.

TABLE 1-5: Environmental Hazards in School

Nature of Hazard	Type of Hazard	Source	Route of Exposure	Possible Effect	Remediation or Prevention Strategies
School Materials: Lead Pesticides Cleaners, solvents, paints Art supplies Lab materials	Chemical/ biological	Intentional appearance in school Result of inadequate handling, use, storage, labeling	Dermal/oral	Exposure at high concentrations: poisoning, chronic illness	Proper handling, use, storage; better education
Indoor Air Quality Asbestos Radon Other air contaminants	Radiation/ chemical/ biological	Unintentional appearance in school; result of inadequate ventilation	Respiratory	Chronic lung disease Sick building syndrome	Redesign; maintain heating, ventilation, and air conditioning
School Location: Electromagnetic fields Hazardous waste sites Noise	Radiation/ chemical/ injury	Siting and location of school	All	Results from low-level exposure: chronic illness/ loss of hearing	Move school/ prudent avoidance
Infectious Disease	Biological	Communicable pathogens	Respiratory/ oral	Infectious disease	Hygiene

SOURCE: Office of Technology Assessment, 1995.

health risks to students in school or are perceived as such by many in the community. The materials covered in this category include lead, pesticides, and other hazards rising from supplies and materials used in arts, industrial arts, and science courses. Exposures to high concentrations of some of these materials can lead to poisoning, but the effects from long-term exposures are more varied and less well understood and documented.

Poisoning

Chemicals that are toxic at very low levels are considered poisons. Exposures to them are often reported to regional poison control centers, and those reports are subsequently collected into a database by the American Association of Poison Control Centers (AAPCC), the professional organization for regional poison centers. In 1993, the AAPCC received about 1.75 million reports of exposure to poison (16), about 55 percent of which were to children under 5 years of age. Approximately 260,000 reported exposures occurred in children ages 5–19, nearly 15 percent of the total.

About 20,000 exposures occurred in schools, but some of these were not to school-aged children. The in-school exposures include all exposures, to staff as well as students, and all schools, including preschools and universities, not just elementary and secondary schools. The data suggest that relative to households, students in schools are at less risk from most poison exposures. At most, 7 to 8 percent of exposures to poison among school-aged children occur in school. In accordance with that estimate, an analysis of the 1988 National Health Interview Survey determined that about 5 percent of poisonings occur in school, compared to 80 percent at home (30).

The AAPCC database recorded exposures to school-aged children to a variety of substances possibly found in the school environment and discussed in this report (15,16). Art and craft materials generated over 4,700 exposures. The AAPCC system reported more than 7,500 pesticide exposures and 16,000 exposures to selected indoor air contaminants in 1992. Presumably, the school environment should have better supervision of the children and better instruction on the proper use and handling of these materials than nonschool environments. However, sporadic in-school inspections revealed that many instructors and others responsible for handling hazardous material were inadequately trained or that the schools failed to develop proper care and storage facilities for these materials. The underlying data and existing studies suggest the presence of toxic materials in schools, yet few efforts are made at determining actual exposures to schoolchildren.

In contrast to the AAPCC data, which reported only possible poison exposures and not the resulting health effects, the National Center for Health Statistics (NCHS) examines hospital discharge records and conducts household surveys to assess impacts of poisoning and injury. For poisoning from drugs and other chemical substances, NCHS estimated that in 1992, poisonings hospitalized about 47,000 school-aged children, of which 191 died. Data are not kept on whether these poisonings occurred in school or at home.

Lead

Lead is recognized by many public health authorities as the foremost environmental health hazard to children (41). Even low levels of lead exposure during preschool years can produce adverse effects on intelligence and behavior. Once absorbed into the child's body, lead can exert adverse effects that vary according to dose and age at exposure. While school-aged children may not be as susceptible as preschoolers to low-level exposures, higher exposures at any age can result in lead poisoning, with the major concerns being adverse effects to the nervous system.

Lead exposure from all sources, whether in the home or the school environment, is cumulative. While it is difficult to rank sources in terms of their contribution to the overall problem of childhood lead poisoning, lead-based paint is considered of premier importance, followed by leaded gasoline fallout into dust and soil, and then by lead in drinking water (23).

OTA was not able to identify any studies that examined the contribution of lead in preschools or schools either to total lead exposure or to adverse health effects in children. The only studies uncovered are those monitoring drinking water or paint lead levels in some facilities in selected areas of the United States. These studies do not systematically and comprehensively assess the presence of lead in preschools and schools nationwide, in contrast to the data available for United States housing. Nor do they examine lead levels in all media combined—paint, drinking water, and soil. They focus primarily on drinking water, despite the fact that this source is not the greatest contributor to the problem of childhood lead poisoning. Finally, the preschool environment, where children are at greater risk because of their age, has been studied far less than the school environment.

The existing data do not demonstrate that the level at which students are currently exposed to lead in classroom or school facilities constitutes a significant risk in itself. **However, given the limited extent of environmental monitoring of preschools and schools where lead is likely to be present, the risks from all sources of lead exposure warrant further evaluation.**

Pesticides

Despite their uses and benefits in schools, pesticides can also pose a public health problem. The health effects known or suspected to arise from pesticide exposure are rather well established. Generally, exposures to high concentrations of pesticides can result in acute toxicity, but far more controversial than poisoning is determining the health effects from chronic exposure to low doses of pesticides. Existing exposure and toxicity data are insufficient to assess these risks in schools.

The California Pesticide Illness Surveillance Program (CAPISP) identifies school exposures in its reporting system, although it does not report the amount of exposure. From 1982 to 1991, student exposures represented 0.6 percent of total pesticide exposures (15,700) and 1.2 percent of total nonagricultural exposures (8,594) reported to CAPISP. During that 10-year period, the program recorded an average of about 10 students exposed a year, although the numbers ranged from zero to 40.

OTA could not find evidence that in-school exposures presented a greater health threat than exposures outside the school environment for school-aged children. Most exposures that did occur in schools were to school staff, who were often untrained in pesticide handling and application. Those cases in which students became ill from pesticide exposures resulted almost entirely from poisonings following inadvertent use, an accidental spill, or intentional or unintentional ingestion. Clearly, inadequate data exist on which to base an assessment of risk from pesticide poisoning.

However, the available data for certain pesticides suggest the potential for adverse health effects and that children may be more susceptible to toxicity with certain pesticides than are adults. Moreover, schools may contribute to the cumulative impact of all the exposures that the student may receive in his or her daily life. Consequently, the steps taken by state and local agencies to promote either pest control strategies that reduce pesticide use or the use of pesticide alternatives in schools seem appropriate (box 1-B).

Other School Materials

In addition to lead and pesticides, other potentially toxic materials can be present in the school environment, in particular, agents used for school maintenance and as teaching aids in the classroom. The Center for Safety in the Arts (CSA), the largest nonprofit clearinghouse on art safety information (19), has identified toxic materials used in arts and industrial art classes, such as lead in ceramic glazes and solvents in paints. They have also presented information on possible exposures to potentially toxic material found in science and other courses in elementary and secondary schools.

Despite many potentially hazardous chemical and biological materials, few data demonstrate that these are making students ill. The sparse data offer random case reports of mishandled materials, but OTA found few case studies of exposures and fewer cases of illness. In fact, CSA claims that most of the reports of illness they receive come from teachers, who are made ill from long exposures in school, as well as from frequent at-home exposures (18).

Ample evidence exists that some of these materials are health hazards: the presence of metals—lead and mercury—and organic solvents—trichloroethylene—all present health risks, especially to school-aged children. These materials cannot be taken lightly or ignored. However, OTA could not find a substantial database demonstrating school exposures, let alone data on illness arising from them. Too little information is available to estimate the likelihood that children become ill following school exposures.

Indoor Air Quality

Indoor air quality considers the thermal environment—temperature, humidity, and air movement—and air contaminants. This report examines the presence of physical, chemical, and biological contaminants in schools. Harmful indoor air hazards include asbestos, which is present in some building materials; radon, a naturally occurring radioactive gas; combustion products; various volatile compounds; and noninfectious biological materials.

Indoor Air Quality in School

Beyond the data on asbestos and radon in schools discussed below, there are no national surveys of indoor air quality (IAQ) in schools. Some state indoor air quality programs exist, however. To provide some information about IAQ problems in schools across the nation, OTA reviewed requests made to the National Institute for Occupational Safety and Health by school teachers and staff for Health Hazard Evaluations (HHEs). OTA analyzed the requests for investigations in 26 schools, to provide a picture of the current nature of school IAQ problems. The health complaints suffered in these schools—neurological

BOX 1-B: Integrated Pest Management in School

Rather than using conventional pesticides to kill pests after they have become a problem, integrated pest management (IPM) approaches the pest problem from a different angle, emphasizing prevention and reduction of the source of the pest problems rather than trying to get rid of all of the pests at once. Comprehensive information regarding the lifecycles of the pests and their interactions with the environment, such as food and habitat, are used instead of relying solely on chemical-based pesticides to eradicate the problem. Through preventative measures, such as education of janitorial staff and improved janitorial practices, landscaping, occupant education, and staff training, IPM creates inhospitable environments for the pests by removing basic needs like food, moisture, and shelter. This use of natural controls can minimize the use of pesticides, therefore reducing possible hazards to people, property, and the environment. The IPM programs do not completely eliminate the use of pesticides, but these measures can help to reduce the amounts used and the exposure to them.

Most school districts do not require that IPM programs be adopted. However, many school districts across the country, including Eugene, Oregon; Conroe, Texas; Dade County, Florida; Montgomery County, Maryland; Cleveland Heights, Ohio; and elsewhere, have voluntarily integrated IPM programs into their pest control management.

Evaluating the costs is almost always a concern when initiating a new program such as an IPM program. IPM programs reduce pesticide use, thereby reducing possible health problems (potential liability) and costs (materials). Long-term reductions in the purchase of pesticides can offset the initial one-time expenses, including structural and grounds modification. Labor costs, however, usually are higher for IPM programs than they are for conventional pest control programs.

Setting up an effective IPM program will take time, money, and the support of all of the participants, including faculty, students, and staff. IPM programs are proving to be a viable alternative to conventional pesticide programs in the California cities of Los Angeles and San Diego.

SOURCES: Dade County Public Schools, Department of Safety, Environment and Hazards Management, *Integrated Pest Management Procedures*, September 12, 1994. Northwest Coalition for Alternatives to Pesticides, "A Better Way: Integrated Pest Management (IPM)," *Getting Pesticides Out of Schools*, 8–13. U.S. Environmental Protection Agency, *Pest Control in the School Environment: Adopting Integrated Pest Management*, EPA 735-F-93-012, August 1993.

effects, headaches, fatigue, dizziness, and throat and eye irritations—reflect the subjective and rather nonspecific nature of the health effects resulting from IAQ problems, including "sick building syndrome" (SBS). SBS is used to describe situations in which adverse, often general and nonspecific, health effects are associated with a building, but the exact cause is unknown.

Specific Indoor Air Contaminants

Although many possible air contaminants may exist in the school environment, OTA considers asbestos, radon, environmental tobacco smoke, volatile organic compounds, combustion byproducts, and biologic organisms as agents worthy of special attention in IAQ issues. These are not the only agents in indoor air associated with health effects, but they are among the best studied and of most concern. Although some information exists about the presence of these agents in schools, there is little direct evidence linking in-school exposures to the diseases discussed. Instead, information is primarily from studies in highly exposed occupational populations—insulation workers for asbestos risks, miners for radon risks, etc.—studies of other nonstudent populations, and animal studies.

Asbestos

About 31,000 primary and secondary schools in the United States have asbestos-containing building materials in some form: insulation and fire protection in heating plants and distribution systems, sprayed-on material for structural fire protection, asbestos-containing tiles, and asbestos-containing plasters, where the asbestos contributes to sound dampening as well as fire resistance (10).

For all of its useful properties, asbestos has a definite downside. Exposures to asbestos are associated with increased occurrence of mesotheliomas (cancers of the lining of the chest or abdomen), but the type of asbestos most commonly used in buildings—chrysotile—is generally considered to present less of a cancer risk than other types. Also most lung cancer cases among asbestos workers occur in smokers; the risks for nonsmokers are much less. Finally, cancer risk decreases with reduced exposures (10).

Following their measurements of asbestos levels in schools, Mossman et al. (20) and Corn et al. (6) calculated the risk of lung cancer and mesotheliomas from measured concentrations of asbestos in schools in the absence of any abatement. The calculated lifetime risks from exposures to asbestos levels of 0.00017 to 0.00024 f/m^3 over a period of five to six years range from 0.3 to 6.5 cancers per million people. This is equivalent to about two to 60 lung cancers per year, out of the entire school population of 46.4 million students.

There is a long lag (usually 20, 30, or more years) between the first recorded occupational exposures to asbestos and increases in asbestos-related cancers. It must be assumed that any cancers that might result from in-school exposures would occur after a similar lag. As sources of asbestos decline nationwide, any in-school exposure might be a child's only contact with the material.

Radon

Radon is a naturally occurring radioactive element that can move from soil and rocks into air and water, and through air and water into homes and other buildings. Radon is concentrated inside buildings because structures retard its dilution into the enormous volume of outside air; thus, "environmental exposures to radon" refers to exposures inside buildings.

The Environmental Protection Agency and the Department of Health and Human Services (44) as well as several independent scientists (17,27) have calculated that environmental exposures to radon are associated with about 13,000 to 15,000 lung cancer deaths annually in the United States. That risk, based on studies of underground miners who were exposed to radon in the course of their work, is the largest cancer risk that the Environmental Protection Agency associates with any environmental exposure (38). If there are any deaths due to exposure as children, these deaths will be decades in the future and mostly among smokers, who are at a much greater risk of getting lung cancer following radon exposure. EPA has established 4 pCi/L as an "action level" (38), and it recommends that actions be taken to reduce any inside radon concentration above that level.

In its *National School Radon Survey: Report to Congress*, EPA made short-term radon "screening measurements" in 927 public schools over seven-day periods during February and March 1991, and long-term radon measurements in 100 schools over the period December 1990 to May 1991. The short-term screening measurements indicate that 2.7 percent (± 0.5 percent, not shown on table) of the tested school rooms had radon at concentrations $\geq$ 4 pCi/L. The percentage of rooms at concentrations $\geq$ 4 pCi/L as determined by the long-term measurements was 1.5 percent (± 1.2 percent).

On average, schools have slightly lower radon concentrations than homes: about 0.8 pCi/L in schools versus 1.25 pCi/L for the average home. Thus, on average, a student faces about equal or slightly lower risk from radon spending the same amount of time in school than at home. By assuming that students will be exposed to the average in-school radon levels for the 12 years of school, it is possible to estimate the numbers of future lung cancer deaths per year due to exposure while in school. This ignores the differences in the distribution of radon among schools in various parts of the country. A one-year exposure to the average in-school level of radon results in 64 cancer deaths, with about half of the total risk borne by high school students that smoke.[19] The risks estimated for in-school exposures are about 10 percent of the risks for school-aged children from residential radon, due to both the slightly lower radon concentration and the considerably lower amount of time spent in school. These deaths are in addition to the 15,000 lung cancer deaths EPA estimates for residential exposures each year in the United States and the 3,000 deaths associated with outdoor exposures.

Only in what appear to be exceptional circumstances do in-school exposures make significant contributions to lifelong radon exposures, which, at certain levels, are unavoidable. In contrast to asbestos, exposure to radon will likely occur throughout a child's lifetime.

Other Air Contaminants

The presence of other air contaminants poses possible hazards in schools. OTA examined the available illness, exposure, and health effects data for environmental tobacco smoke, volatile (and semivolatile) organic compounds, combustion products, and biological contaminants. In each category, ample health effects data suggest that exposure to particular agents can lead to adverse health effects, especially in school-aged children. Nevertheless, little evidence exists to demonstrate that school children are being exposed to dangerous levels of agents. The available data come from case studies of a single school or a few schools with specific problems. Hence, inadequate data are available to conduct a quantitative assessment of the health risks in schools from these indoor air contaminants.

School Location

Parents, teachers, and administrators often express concern about, and even fear of, hazards arising from the location of a school. Environmental hazards associated with location can come from the community, such as polluted air or water, or from placement of the school on or near hazardous waste sites or close to power transmission lines. This report discusses some of the risks associated with those hazards; however, insufficient data exist to assess their risk quantitatively or even qualitatively.

Electromagnetic field (EMF) exposure is among the most uncertain of the environmental risks described in this report. Although concerns have been raised that prolonged, elevated exposures may place individuals at increased risk, there is still no consensus among scientists as to whether power frequency EMF exposure presents a health risk. Those who believe a cancer risk exists are in general agreement that EMF does not cause cancer but instead acts as a promoter— that is, a cancer may be more likely to occur when an individual is exposed. The magnetic field component of power frequency EMF—which is generally unperturbed by buildings and walls, and penetrates the human body—is the typical focus of such concerns.

Electromagnetic fields are ubiquitous in the home and school. Each of these environments is replete with opportunities for exposure. Power frequency EMF exposure may come from sources inside buildings, such as electrical devices and wiring, or outside sources, such as transmission or distribution lines. A child's exposure, whether in the home or the school, varies greatly: it depends on the number of sources, their intensity and configuration, their proximity to the child, and the amount of time he or she spends in their presence. The impact of exposures at school and the school's contribution to a child's overall exposure are almost impossible to predict, even if the sources within both the school and the home are well characterized. Much depends on the child's dose, and no one knows exactly what measure of dose is most

[19] A Centers for Disease Control and Prevention survey indicates that 70 percent of high school students had tried smoking, even one or two puffs, and 28 percent were considered "current cigarette users," having smoked one or more cigarettes on one or more of the 30 days preceding the survey (40). For these calculations, OTA assumes that 28 percent of the high school population (grades 9–12) smoke; younger students are assumed to be nonsmokers.

informative or how variations in dose might affect the response to the exposure.

Knowledge of power frequency EMF exposure at school comes from a limited number of studies. We do know whether levels at some schools equal or exceed those associated with increased incidence of certain forms of cancer in some residential studies. However, these residential studies of cancer address prolonged exposures (more than 12 hours per day), and their results may or may not be applicable to school exposures of equal magnitude. We also know that transmission lines are just one of many sources of exposure and not necessarily the most important source. So much of the school research has been driven by public concerns about transmission lines that other sources of exposure, particularly sources inside the school, have been neglected. Finally, we know that EMF levels vary from one school to another, vary among locations within a school, and vary over time at any one location. Additional research is needed to better characterize school EMF exposures and exposure sources so that more informed decisions can be made as our knowledge of health effects improves.

Infectious Disease

Infectious diseases are spread mostly by student to student contact in the course of a normal school day, and inadequate ventilation or overcrowding in schools may contribute to the spread of diseases for which the airborne route is a factor. Infectious conditions represent a substantial cause of morbidity and mortality in school-aged children. On top of that, researchers and public health officials are raising additional concerns about infectious diseases as new infectious problems continue to occur, such as human immunodeficiency virus (HIV) infection and streptococcal toxic shock syndrome, and new infectious disease challenges, such as the emergence of drug-resistant bacteria and mycobacteria.

Substantial data are available from a variety of sources on many of the infectious conditions that occur in school-aged children. Sources of data include national surveys, disease-specific surveillance, focused epidemiologic and laboratory research, and national or hospital-based databases. Nevertheless, the source of an infectious disease is typically not known; thus, there are no data on infectious disease from the school environment. This section presents the available data on infectious disease in school-aged children regardless of origin, from the results of a national household survey and cases of notifiable diseases.

The NCHS National Health Interview Survey (NHIS) is a continuing nationwide survey of households. The NHIS data of the incidence and severity of infectious disease in school-aged children are shown in table 1-6. The table shows that over 82 million acute conditions occurred in 1992 for children 5–17 years old, but does not represent all of their diseases. The acute conditions presented here include infective and parasitic diseases, such as common childhood diseases (e.g., measles), respiratory conditions, such as influenza, and acute ear infections. These infectious diseases were responsible for 81 percent of the lost school days from all acute conditions, which include injuries and digestive system complaints.

The NHIS results can give an indication of the health impact of a particular condition. Respiratory diseases account for the greatest number of acute conditions, influenza being the most prevalent. Accordingly, more school days are lost from respiratory conditions; common childhood diseases account for the largest numbers of lost school days per condition.

Data on the reported occurrence of notifiable diseases are collected and compiled by the Centers for Disease Control and Prevention from reports to the National Notifiable Diseases Surveillance System, which has morbidity information for 49 currently notifiable conditions, for which notification to public health authorities by the attending physician is mandatory. Many common diseases do not require reporting. According to the reported cases of infectious disease in the United States for school-aged chil-

TABLE 1-6: Number of Acute Conditions and School-Loss Days in Youths 5–17 Years of Age from the National Health Interview Survey, 1992

Type of Acute Condition	Acute conditions		School loss days		School loss days/ condition
	Number (in thousands)	Rate (per 100 youths)	Number (in thousands)	Rate (per 100 youths)	
All acute conditions	112,340	239.9	164,797	351.9	1.47
Infective and parasitic diseases	21,155	45.2	40,751	87.0	1.92
Common childhood diseases	2,399	5.1	12,225	26.1	5.12
Intestinal virus, unspecified	5,122	10.9	6,312	13.5	1.23
Viral infections, unspecified	5,826	12.4	7,910	16.9	1.36
Other	7,808	16.7	14,303	30.5	1.83
Respiratory conditions	55,783	119.1	85,509	182.6	1.53
Common cold	16,562	35.4	21,978	46.9	1.32
Other acute upper respiratory infections	8,303	17.7	13,321	28.4	1.60
Influenza	27,653	59.1	43,532	93.0	1.57
Acute bronchitis	1,922	4.1	3,517	*7.5	1.83
Pneumonia	584	*1.2	2,001	*4.3	3.58
Other respiratory conditions	758	*1.6	1,160	*2.5	1.56
Acute ear infections	5,424	11.6	7,149	15.3	1.32

SOURCE: Benson, V. and Marano, M.A. Current estimates from the National Interview Survey, National Center for Health Statistics, *Vital Health Stat*, 10 (189), 1994.

dren, ages 5–19, gonorrhea was the most reported disease in 1992, with over 151,000 cases. This was about four times greater than the second most numerous category, chickenpox, with over 37,000 cases. Hepatitis A had 7,565 cases, and two diseases arising from contaminated food and water are the next most numerous cases: salmonellosis with 5,943 cases and shigellosis with 5,193. Finally, authorities reported 4,060 cases of syphilis and 2,970 cases of aseptic meningitis.

The school environment may put students at a greater risk than other environments for catching many infectious diseases. However, this remains a speculative determination since the school's contribution to disease is rarely determined. Nevertheless, the school environment would appear to be an incubator for many diseases. Respiratory infections, in particular, can spread from student to student during interactions in crowded classrooms. Two of these, pneumonia and influenza, led to the deaths of about 190 school-aged children in 1992.

In that same year, infection with the human immunodeficiency virus (HIV) contributed to the deaths of about 150; while its transmission may occur in schools, the data are inadequate to estimate the importance of school contacts, although about half of fatalities are in the pre-adolescent population (5 to 9), which suggests these deaths are not attributable to school contact.

In box 1-C, OTA presents those disease categories that warrant more attention than others based on their implications for schoolchildren and public health. Based on those categories, OTA examined the available information on illnesses of school-aged children from these specific diseases: meningococcal infections, viral respiratory infections, Group A streptococcal infections, Hepatitis B and human immunodeficiency virus infections, and food poisoning.

Infectious diseases are among the best understood and documented causes of disease in

BOX 1-C: Diseases of Concern to School-Aged Children

Based on interviews with infectious disease experts, the Office of Technology Assessment (OTA) considers the following disease categories as warranting more attention than others based on their implications for schoolchildren and public health.

1. **Diseases with high incidence:** Diseases such as respiratory viral infections, especially influenza, are noteworthy because they occur so commonly. Other diseases of high incidence in schools include common childhood diseases and conditions such as head lice, conjunctivitis, strep throat, otitis media (ear infection), and mononucleosis. These conditions inflict costs not only on the child in terms of lost school days but also indirect costs due to parents' lost time from work.

2. **Diseases of high severity:** Diseases such as pneumonia, AIDS, and meningococcal infections (meningitis and bloodstream infections) that are not common but have a high case fatality rate (CFR) in school-aged children are a significant public health problem. CFRs refer to the deaths attributable to a specific condition in relationship to the reported cases of the condition. Bacterial meningitis used to have a fatality rate of more than 50 percent, but more treatment has reduced the rate to 10 percent.

3. **Diseases with a major impact on the public health systems:** Diseases that occur in outbreaks in schools may deplete public health resources in an affected community. Such impacts may include investigation and intervention in foodborne disease outbreaks or mass immunization campaigns for meningococcal disease clusters.

4. **Diseases that spread from school children to families and the community:** Schools may act as an "incubator" for certain diseases that then spread to families and the community. Influenza and group A streptococcal infections are rarely severe in children but may cause substantial morbidity and mortality in infected family members, especially the elderly. The spread of antibiotic-resistant bacterial infections initially within childcare settings and subsequently into the community is another example of such a problem.

5. **Diseases that are becoming increasingly common ("emerging infections"):** Many microbiological agents can adapt and even mutate in response to their environment. Often these adaptations can result in organisms that can proliferate where they could not before, or previously harmless organisms that can become disease-producing agents. These changes can create new infectious diseases (HIV infection and group A streptococcal toxic-shock syndrome), new problems associated with well-recognized infections (drug resistance in bacteria and tuberculosis), and changes in the epidemiology of infectious disease (clusters of cases of rheumatic fever). Infectious disease in the school environment is an important focus for studying these emerging diseases because it provides an opportunity for surveillance, research, and the development of preventive interventions.

6. **Diseases that offer substantial opportunity for prevention in schools:** This category includes diseases such as meningococcal infections and influenza, for which effective vaccines already exist, and efforts are focused on determining the most cost-effective approach for immunization; respiratory syncytial virus and parainfluenza virus, for which new vaccines are being developed that may offer the opportunity for prevention; foodborne illness, where application of proper food handling practices can eliminate outbreaks; and diseases such as hepatitis B and HIV infection, where schools provide a focus for education on risk factors for illness and on prevention through behavior modification.

SOURCE: Office of Technology Assessment, 1995.

school-aged children. The transmission of disease through social interaction and the often crowded conditions at school suggest that schools are a primary incubator for the growth and spread of infectious organisms; however, OTA could find little national data linking illness specifically to the school environment. Although case studies document the outbreaks of disease and disease clusters emanating from schools, more information is needed on the role of schools as a source for the spread of infectious and foodborne disease.

USING THE DATA

Chapters 3 and 4 of this report are compilations of information about health and safety risks in schools. However, decisions on whether to deal with these risks require more than listing the health and safety data. Decisionmakers likely will want an understanding not only of the hazard but the perceptions of the hazard, why it exists, and what it would take to remove it. When deciding which risks to address first, many people naturally tend to order things by their size or severity, yet simple point estimates of risk often do not convey the spectrum of other important factors. This section briefly reviews several subjective risk attributes that decisionmakers may want to consider in efforts to compare and rank diverse in-school risks. In addition, OTA briefly reviews different types of comparative risk assessment (CRA), that is, a process for using risk estimates, such as those presented in this report, to help set priorities for risk reduction.

Risk Dimensions

Risk attributes, or "dimensions" of risk, can be grouped into three categories: magnitude of the risk; social aspects of the hazard; and feasibility, cost, and other implications of reducing the risk.

Risk magnitude refers to the quantitative estimates of the likelihood of adverse health effects arising from the hazardous conditions. This category reflects the more conventional notions of the number of deaths or cases of injury and illness and their severity. There are several common measures for quantifying risk magnitude. This report used number of incidents and incidence rates as measures of injury or illness in the school population, and lost school days as a measure of severity. There are also measures of the individual probability of risk or the risk to the population. One measure of particular relevance to this report is in the number of years of life lost, rather than the numbers of lives lost. The death of a child is then weighted much more heavily than that for an elderly adult.

Some reasons for wanting to reduce risks extend beyond the benefits to health and safety, but rather relate to the social context of a risk. Some risks are more worth taking—or bearing—than others. This difference is largely governed by the perceived benefits that accompany the risk. Football, for example, is among the most hazardous athletic activities—in terms of the number of injuries—in which high school students participate, yet the perceived benefits of athletic accomplishment and social recognition encourage continued participation in it.

Fear can be one of the most significant dimensions of risk, especially in schools, and one that varies widely across individuals and communities. Contributing to the fear of a hazard is the extent to which individuals can or cannot control the risk through personal action. Parents may fear their child's in-school exposure to asbestos or to a student carrying a weapon because they cannot control it, but they are probably less afraid of the exposures to most infectious pathogens—even though the bacteria and viruses are responsible for more lost school days—because they have more control from antibiotics, vaccines, and rest. The irreversibility of an illness or injury also adds to the fear associated with a hazard; the more irreversible the effect, such as spinal cord injury or HIV infection, the greater the fear.

Another factor is the desire to focus attention on reducing risks where in so doing injustices can also be redressed and blame for the hazard can be affixed. Inadvertent release from a nearby hazardous waste site, or an industry that exposes schoolchildren to toxic material, generates more public interest than the risks from radon—even though the risks of the latter are probably greater—because radon is a natural gas and no one is to blame for children's exposure to it.

An especially important consideration now confronting schools is the cost and feasibility of reducing the risk of a hazard. Small risks that are cheap and easy to eliminate may deserve priority attention, whereas even very large risks may not emerge as priorities from a thorough risk comparison if reducing them would be technically infeasible or prohibitively expensive. Metal detectors, for instance, may provide protection from firearms in schools, but they are expensive and school boards must decide if the risks in their schools justify the costs. The risk of the intervention itself, the dimension of "offsetting or substitution risks," arises whenever reducing one risk would create new risks in so doing. For example, closing the schools to remove asbestos exposes the children to risks of being out of school.

Comparing and Managing Risks

This course of making decisions about which risk reduction measures to undertake leads to suggestions for the use of comparative risk assessment (CRA). CRA remains a controversial and mostly untested process. Nevertheless, efforts at federal, state, and local levels to undertake CRA to establish risk priorities and strategies for reducing them suggest the possible utility for some of CRA's methods and social processes. This section presents some of these processes and the nature of the information needed for them.

Much of the discussion of the process for comparing risks revolves around the distinctions between the so-called "hard" and "soft" versions of risk-based priority setting (7). The "hard" version—also referred to as "expert-judgment"—involves the use of a small group of experts to develop estimates of the magnitude of various risks and a ranking of risk reduction opportunities. The "soft" version uses a societal representative group—composed of citizens as well as experts—that works together to generate a more "impressionistic" ranking of risk based on many factors in addition to quantitative estimates of deaths, illness, and injuries.

The open process that is part of the soft version of CRA helps to inform risk assessors about public values and the relative importance the community places on subjective risk attributes such as fear. By involving the public, a soft CRA can go beyond probability estimates of risk and incorporate ethical and political concerns, which are usually neglected in risk assessments (33). Comparison and ranking inevitably involve incorporating these value judgments as well as the scientific estimates and measurements. The process helps to educate the public on the scientific and technical issues associated with risk assessment, and helps to educate everyone involved—parents, school boards, risk assessors, and others—about the nature of suspected risks.

After ranking risks, the next step involves comparisons of risk-control strategies, where feasible. Setting priorities for risk reduction is more than simply ranking risks. Setting priorities means to guide where *resources* should flow. The *biggest* problems may bear little resemblance to the highest priorities for risk reduction. Decisionmakers are likely to want to incorporate social, political, and technical factors as well as economic costs.

The purpose of comparing the wide range of risks in schools is to help allocate or reallocate resources among the many possible risk-reduction options, including the option of no action on one or more perceived risks. The public may be delighted to have funds spent more efficiently, but probably not at a cost of visibly greater risks to students. To such a combustible, emotional debate, the need for clear, objective analyses and straightforward, understandable information becomes increasingly clear. This report, then, consists of a first step in this process.

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Issues in School Health and Safety 2

Schools, like all buildings and institutions, harbor some risks. Some of the illnesses and injuries in schools stem from preventable or reducible hazards. Nevertheless, compared to other places where children live and play, schools are often safer environments. This finding must be qualified by the paucity and occasional poor quality of data—or even the absence of information about some hazards.

Children daily confront a variety of risks, in or out of school. In 1992, children ages 5 to 17 suffered 13 million injuries and some 55 million respiratory infections, which contributed to their missing about 214 million school days, roughly 460 days for every 100 students. Unknown are the possible long-term health consequences, the impact of the lost learning opportunities, or the care-giving problems faced by families.

Averaged over the year, school-aged children spend about 12 percent of their time in school, and some portion of these injuries and illnesses arise in connection with the school environment. Since government requires school attendance, it ultimately bears responsibility for children's health and safety while they are there. While local, county, and state governments bear most responsibility for the operation of schools, the federal government has taken a role in health and safety issues, as reflected in the 103d Congress considering 66 bills that referenced the "school environment" and 51 that were directed at the goal of "safe schools." Congressional concern led the House Education and Labor and Energy and Commerce Committees of the 103d Congress to request this report, which examines the scientific data on the risks for injury and illness in the school environment.[1]

Important interactions between the student's home life—such as the presence of only a single parent, poor family dynamics, limited supervision, or poor nutrition—and school-connected behavior and health and safety problems are beyond the scope of this report, as are mental health problems of children and adolescents. "Behavioral" risks, such as drugs and pregnancies, are high on the public's list of concerns, but they are not included in this report. Two OTA reports, *Healthy Children: Investing in the Future* (25) and *Adolescent Health* (26), provide broader information about the health of children

[1] In the 104th Congress, the House Education and Labor Committee was renamed the Education and Opportunity Committee and the House Energy and Commerce Committee became the Commerce Committee.

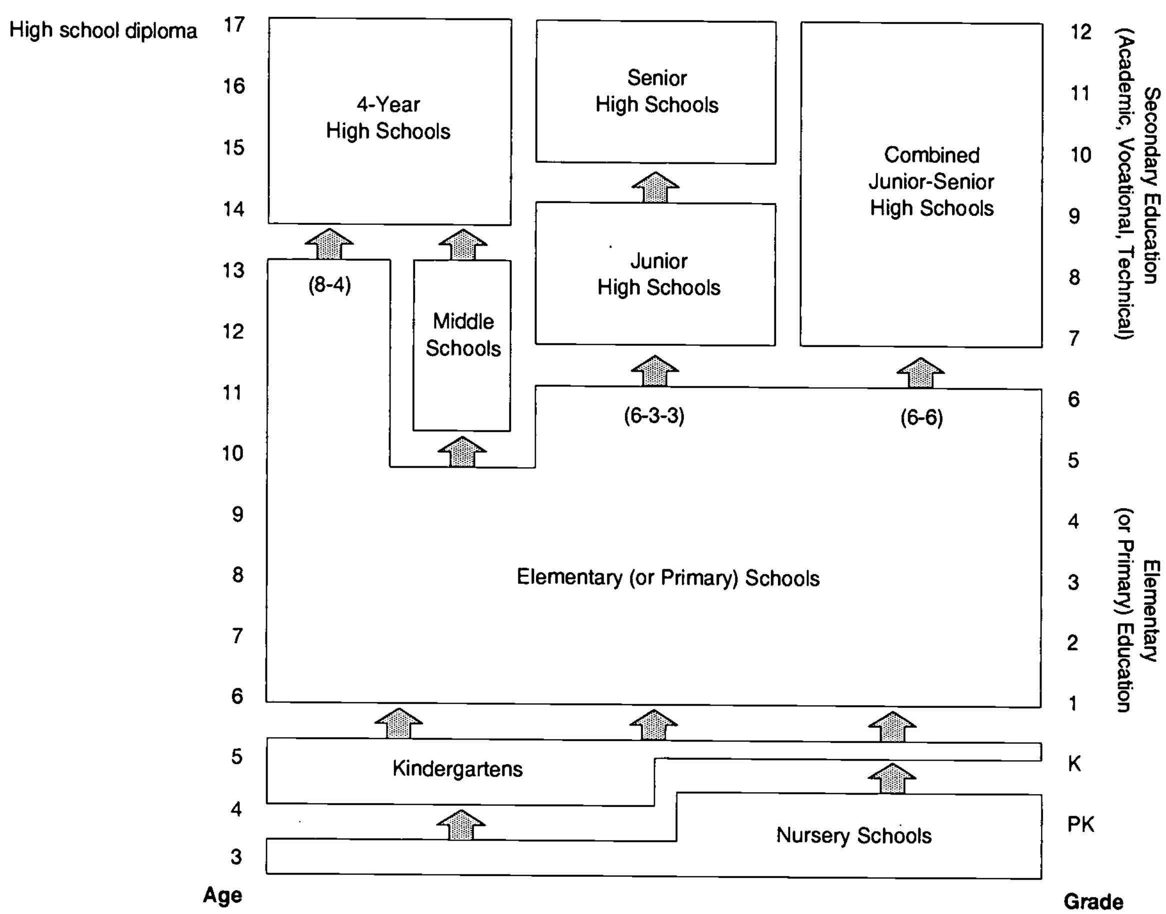
and adolescents through 18 years of age; this report is narrowly centered on health and safety risks to students while in school.

This chapter introduces the issues of school health and safety. It initially describes the student population and the school environment. The rest of the chapter is devoted to introducing concepts concerning health and safety data: the nature of the studies generating them, how the data are collected and interpreted, and the inherent difficulties in obtaining reliable and credible information. It ends by discussing the significance of risk estimates in deciding which risks need to be reduced, strategies for reducing them, and to what levels they should be reduced.

Student Population

The student population covered in this report spans the ages 5 to 18, which correspond to grades kindergarten through the 12th grade (see figure 2-1). According to census figures (31), over 46 million children were enrolled in the 109,000 elementary (kindergarten–8th grades) and secondary (9th–12th grades) schools for the 1990 school year, and a projected 50 million will enroll for the fall of 1995 (see table 2-1A and 1B). Except for the section on lead, the report does not cover nursery schools and students below the age of 5, nor does it cover the provision of health care in schools.

FIGURE 2-1: The Structure of Education in the United States



SOURCE: U.S. Department of Education, National Center for Education Statistics.

TABLE 2-1A: Enrollment in Educational Institutions by Level and Control of Institution: Fall 1990 to Fall 1995 (in thousands)

Level of Instruction and Type of Control	Fall 1990	Projected Fall 1995
Elementary and secondary education[a]	46,448	50,709
Public	41,217	45,049
Private	5,232	5,660
Grades K-8[b]	33,973	36,668
Public	29,878	32,275
Private	4,095	4,393
Grades 9-12	12,475	14,041
Public	11,338	12,774
Private	1,137	1,267

[a] Includes enrollments in local public school systems and in most private schools (religiously affiliated and nonsectarian). Excludes subcollegiate departments of institutions of higher education, residential schools for exceptional children, and federal schools. Excludes preprimary pupils in schools that do not offer first grade or above.
[b] Includes kindergarten and some nursery school pupils.

SOURCES: U.S. Department of Education, National Center for Education Statistics, Common Core of Data and "Fall Enrollment in Institutions of Higher Education" surveys; Integrated Postsecondary Education Data System (IPEDS), "Fall Enrollment" surveys; and *Projections of Education Statistics to 2004.*

Almost all information concerning school-based risks comes from studies and reports related to public schools. While the data could be applied to the 5 million children in the 24,690 private schools, this report could not find data suggesting one way or the other the appropriateness of that application.

One admitted data shortfall is limited knowledge about the particular susceptibilities of school-aged children, as age is known to be a major determinant of individual risks for particular illnesses and injuries (1,21). In general, compared to adults, children absorb more of any substance in the environment because of the larger ratios of their skin surface and, lung surface area to body weight and their higher metabolic rates. Because of the ongoing growth processes in children, many injuries, for example to the head, can have long-term health implications. These differences have implications for the interpretation of data on school children since

TABLE 2-1B: Public School Districts and Public and Private Elementary and Secondary Schools: 1990-91

School Year	1990-1991
Public school district	15,358
Public Schools	
Total all schools	84,538
Total all regular schools	81,746
Elementary Schools	
Total	61,340
One-teacher	617
Secondary Schools	22,731
Private Schools	
Total	24,690
Elementary	22,223
Secondary	8,989

SOURCES: U.S. Department of Education, National Center for Education Statistics, Statistics of State School Systems; Statistics of Public Elementary and Secondary School Systems; Statistics of Nonpublic Elementary and Secondary Schools; Private Schools in American Education; and Common Core of Data surveys.

most health studies are conducted on adults, and children may not be adequately addressed in the design or analysis of the data.

School Environment

Schools' primary mission is education; their end product can be considered an educated individual. Given the importance of education for an individual's ultimate happiness and satisfaction and the documented benefits to society of an education (34), disruption of the learning process must be considered an adverse effect. Clearly a sick or injured student, even if he or she attends school, is not as prepared to learn as a well student. A student fearful about assault or other violence on the way to and from school or on the playground is not prepared to learn.

Although the impact of sickness or injury on learning is difficult to estimate, one measure of this impact—used in this report—is the number of school days lost from an injury or illness. Injuries and illnesses resulting in absences from school may impede the learning process: a committee of pediatricians reviewed the medical and educational literature and concluded that "children that are frequently or persistently absent from school tend to perform poorly in school and are likely to drop out before graduation" (34). Further, they cited a number of social implications, including maladaptive behavior and future unemployment and welfare costs, as ramifications of excessive school absence.

School absences stem from many sources, and injuries and illnesses from the school environment make some unknown contribution to them. Even though the contribution of the school environment to a student's health and education has been discussed for decades (6,12,23), our understanding of it remains limited. Complicating our understanding is the lack of knowledge of the environmental, structural, and social hazards found in schools (22), which is partly manifested in not knowing which injuries and illnesses originate in schools and which arise elsewhere.

Despite the lack of knowledge of the hazards in them, schools contribute to student safety by protecting them from most hazards and instructing them on how to live safely in an often dangerous world. School prevents exposures to many of the worst risks. A student sitting at a desk, changing classes in an orderly fashion, and playing in supervised sports is likely to be safer than a child in unsupervised play in a neighborhood playground or park. As discussed in Chapter 1, relatively few deaths (less than 1 percent) occur in schools or school buses from the two leading causes of death in school-aged children, motor vehicles and firearms.

Schools also teach the proper use of potentially hazardous equipment, safe conduct on playgrounds and in athletic activities (like swimming), and respect for others and for dangerous situations. These skills carry over to the nonschool environment since many of the same activities occur off the school grounds. In addition, a growing number of organizations offer school-based programs that teach children the importance of health, safety, and the environment. One of the most notable examples is the Enviro-Cops program in the Dade County school system (see box 2-1). Because of this instruction and because of constant supervision by responsible adults, schools are often a safer place for children than most nonschool environments. Despite the concern for school safety, especially school violence, the overwhelming majority of polled school board members responded that they believed schools are still safe places for students and staff (33).

HEALTH AND SAFETY DATA

Collecting and analyzing data about illnesses and injuries are the cornerstones of efforts to identify and control health and safety risks. Although data and estimations come from different sources and are collected by different processes, certain generalities describe the data for the four kinds of risks that are considered here: unintentional injury, intentional injury, environmental illness, and infectious disease. The sources of data are considered in detail in the appropriate section; the following briefly discusses the nature of the data collection and interpretation.

Nature of Data Collection

Data collection constitutes the first, and in many ways, the most important step in having credible, usable, and understandable information for making decisions. The kinds of data described in this report are usually derived from *surveys* or *reporting systems* that specify what sorts of data to collect. More specific data and, generally, more information important to the interpretation of the data are collected through focused studies.

Despite the obvious desirability of more complete information on the hazards facing children in schools, obstacles to data collection activities exist. Obstacles can be simple, such as the lack of resources—money, expertise, or both—or more complicated, like the fear of being branded a "problem school."

Surveillance: Surveys and Reporting Systems

Surveillance is an active process for collecting, analyzing, and disseminating information on the occurrence of illness or injury (4). The meth-

BOX 2-1: Enviro-Cops and Enviro-Mentors

Enviro-Cops/Enviro-Mentors is just one of many successful programs concentrating on making the world safe for children. The Enviro-Cops and Enviro-Mentors program involves students in projects that teach them to save energy, recycle, and eat well, as well as personal, home, auto, and bicycle safety. The Enviro-Cops program starts with second grade students of the Dade County public school system. It teaches them to be eco-smart while developing their self-esteem and personal safety. More than 225,000 elementary school students have become involved with Enviro-Cops. Many of the Enviro-Cops continue their involvement in the program and return to become Enviro-Mentors, which is the second half of the program and consists of high school and college students who volunteer to be role models for the younger students.

Enviro-Cops take on many issues that affect all of the children of the world. The program incorporates safety issues, including personal safety (for example, eating good food, avoiding guns ("see a gun, dial 911"), and saying no to drugs and alcohol), traffic safety (such as wearing bicycle helmets and seat belts and using child seats for younger children), and environmental safety (like confronting issues such as the use of pesticides, the depletion of the world's resources, and destruction of the world). Enviro-Cops actively help reduce waste, recycle, precycle, and reuse. They learn that their actions do make a difference and that they can make the world safe for themselves, their families, their friends, and everyone else.

SOURCE: ARISE Foundation, *Enviro-Cops Guidebook and Lesson Plans*, 1993. ARISE Foundation, *A 10-Year Retrospective*, 1993.

odology for surveillance activities is basically descriptive. Its functions, however, extend beyond data gathering, as the information forms the basis for action by authorities to control or prevent public health hazards.

Surveillance systems were first developed for illnesses from infectious diseases and more recently are becoming established for other causes of disease and injury. Although disease surveillance began in the mid-1800s in England and Wales, in this country the collection of national morbidity data began in 1878, when Congress authorized the Public Health Service to collect reports of the occurrence of quarantined diseases such as cholera, smallpox, plague, and yellow fever (4). In 1893, Congress passed an act stating that weekly health information should be collected from all state and municipal authorities. This developed over time into a weekly bulletin: the *Morbidity and Mortality Weekly Report* (MMWR), issued by the Centers for Disease Control and Prevention (CDC), which was given responsibility for receiving morbidity reports from states and cities in 1960. National disease surveillance programs are maintained by most countries, and the World Health Organization (WHO) maintains a global surveillance system on quarantined and other selected diseases (2).

In establishing its global surveillance system, the WHO (35) identified 10 distinct sources of surveillance information. Sources of surveillance data relevant to this report include mortality and morbidity data, individual case reports for rare diseases or unusual cases, and the reports of epidemics for clusters of cases. Surveys, such as household or population surveys, can provide information on the prevalence and occurrence of a disease. Demographic information, such as age, and environmental information, such as the presence of lead, are also important sources of data.

Surveillance systems are run from central locations with the objective of monitoring a region—local or national—for any changes in the incidence or nature of particular injuries or illnesses. Surveillance data are often reported by health providers to health authorities, such as the state health department. Reporting can be routine or active for specific cases, but both cases require a standardized process whereby comparisons can be made between and across geography or time.

Data collection forms are distributed to the reporting units, and the completed forms are usually collected with similar forms, sometimes analyzed, and sometimes simply stored away.

Some well-established systems, such as the CDC's MMWR, are designed to disseminate the collected information. Other reporting systems may not disseminate the information as widely because the system may be designed for purely local purposes, or because of other reasons, such as fear of bad publicity. For example, school nurses file reports for observed injuries and illnesses, but these reports are often not released to the public. In any case, regardless of the difficulties of establishing and maintaining a survey or reporting system, these activities must be compatible with other sets of data. Surveys and studies must follow accepted or clearly described protocols if the results are to be informative and useful.

Studies

In contrast to the standardization and routine of surveys or reporting systems, studies can be designed to investigate a particular outbreak or situation, and thus require careful attention to design, execution, and analysis. Studies can be especially informative because they allow researchers to account for the complexity of the school environment and activities by incorporating relevant information from the community, such as lead being released from a nearby smelter. That flexibility also increases the complexity of the study. Epidemiological studies provide most of the relevant data in this report. However, toxicological and human exposure studies also provide important information for determining students' risks.

Epidemiological studies

Epidemiology is the study of the distribution of disease in human populations and the factors that influence the distribution of disease. Epidemiological techniques are used to identify causes of disease and determine associations between disease and risks. There are three basic designs for such studies: descriptive, experimental, and observational. This section provides a simple sketch of the field and defines some terms for the reader with no background in epidemiology. For more in-depth discussions, there are many available references, including Hennekens and Buring (13), Lilienfeld (18), Evans (8), and Brachman (4).

Descriptive epidemiology studies examine the patterns of distribution of disease and the extent of disease in populations in relation to characteristics such as age, gender, race, etc. Sources for descriptive studies include census data, vital statistics data, and clinical records from hospitals and private practices. By examining the differences in disease rates over time, descriptive epidemiology provides clues about disease causation. Descriptive studies can also focus on comparisons of geographical regions.

Experimental epidemiology studies involve a deliberate exposure or withholding of a factor and observing any effect that might appear. In these studies the investigator controls exposure to a risk and assigns subjects, usually at random, to either receive the treatment/risk or a placebo. The effects on the two groups are compared and analyzed. Experimental studies are hard to conduct, however, because of the need for a cooperative and eligible group of individuals who will allow intervention in their lives. Also, ethical reasons (either withholding a beneficial treatment from some subjects or introducing subjects to potentially harmful treatments) may make the study difficult to conduct.

Observational epidemiology studies analyze data from observations of individuals or relatively small groups of people in order to determine whether or not a statistical association exists between a factor and disease. Observational studies have two design options: cohort studies or case-control studies. In either design, the risk factor under investigation should define the groups, which otherwise should be comparable.

Cohort studies look forward (prospective), choosing subjects who are free from the disease under study, but who differ in respect to the risk factor under study. The health status of the individuals in the study group is observed over time to determine whether there is an increased risk of a disease associated with that exposure.

Case-control studies, on the other hand, compare individuals with the disease under study (cases) with individuals who do not have the disease under study (controls). Risk factors that are thought to be relevant to the study are compared between the groups. The extent of exposure to the risk in the case group is contrasted with the extent of exposure in the control group. Because of the presence or absence of the risk factor in the past, case-control studies are retrospective studies.

Toxicological Studies

Most often, the information needed to predict adverse health outcomes from exposure to potentially hazardous chemicals comes from testing substances in animals or through *in vitro* tests, that is, in cells or tissues isolated from animals and humans. Such toxicological studies allow scientists to test chemicals and control conditions that cannot be controlled in most epidemiological studies, such as the amount and conditions of exposure and the genetic variability of the subjects. Toxicological studies are the only means available to evaluate the risks of new chemicals.

Biologically, animals, even the rats and mice typically used in toxicity testing, resemble humans in many ways. A substantial body of evidence indicates that results from animal studies can be used to infer hazards to human health (14,15,16). There are exceptions to this generalization, but each must be proved to be able to set aside the assumption that animal tests are predictive.

Toxicological disciplines can be distinguished by the "endpoint" studied, the resulting disease or the organ affected by exposure to a toxic substance. Increasingly, researchers are studying subtle endpoints other than cancer, such as immunotoxicity (27), neurotoxicity (29), reproductive and developmental toxicity, liver and kidney toxicity, and lung toxicity (28). More attention is also being devoted to studying the effects of long-term (chronic) exposures, rather than the effects of large, short-term (acute) exposures.[2]

Toxicological studies, however, have limitations. Cost considerations limit most animal studies to a few hundred test animals, and in most instances, researchers use high levels of exposure to increase the likelihood of observing a statistically significant effect in a relatively small group of animals. It can also be very difficult to verify any quantitative extrapolation of the results of animal studies to human effects. The reader is directed to the many detailed references in toxicology, in particular Klaassen et al. (17).

Human Exposure Studies

Human exposure studies measure the presence of an agent in air, soil, or food. The most accurate information about exposure is based on monitoring the amounts of a substance to which people are exposed (20). Personal monitoring measures the actual concentrations of a hazardous substance to which people are exposed by using devices that individuals wear or by sampling the food, air, and water they eat, breathe, and drink. Biological monitoring measures the toxicant or its metabolite in biological samples such as blood or urine. Ambient monitoring measures hazardous substances in air, water, or soil at fixed locations. That method is often used to provide information about the exposure of large populations, such as people exposed to air pollution in a region. Often, monitoring data are not available. As a result, assessors often estimate exposures to emissions from a distant source like a factory by using exposure models (20). Exposure models simulate the dispersion of substances in the environment.

[2] For excellent reviews and research papers on the various types of toxicological studies on noncancer effects being conducted, see Environmental Health Perspectives, 1993, vol. 100; in particular see Luster and Rosenthal (19); Schwetz and Harris (24); and Fowler (10).

Difficulties with Data Interpretation

Data, however collected, are usually analyzed for their implications and significance at the local level. These analyses use the results of an investigation—"raw data"—and place it in context of the reliability and the strengths, weaknesses, and limitations of the methods used. Analysts and decisionmakers are best able to do their work when they understand the process of measuring adverse events and the numerical estimates of risk; the nature of the data; and the problems inherent in their interpretation. This is particularly true when the data are being used to support legislation or public health action because of the likely scrutiny and the resulting commitments of resources. Besides estimating the likelihood of injuries and illnesses, analysts and decisionmakers must consider the quality, relevance, and predictive value of the available data.

Data are always limited, and generalizations and extrapolations are often necessary to interpret and apply the available data. Most often, gaps in data, knowledge, or both force the use of assumptions and generalizations in drawing conclusions. Even with sufficient data, however, interpretation can be fraught with difficulties. This section describes some of these difficulties in data interpretation.

Completeness and Generalizability of Data

For some hazards, the only information comes from limited studies of specific populations. It is common practice to generalize results from studies of one or a few schools to schools statewide or even nationally. Two types of generalizations are commonly made: *geographic* generalizations use data from one area, such as urban schools, and generalize to another setting, such as suburban schools. Conversely, national databases can be used to infer risks to certain schools or student subpopulations. Similarly, *temporal* generalizations apply results from earlier studies to current circumstances.

All data-reporting systems confront problems of underreporting, self-reporting, and selection bias. School injury data, for example, rely almost entirely on school-based reporting, for which the common methodological concern is underreporting (11). One study designed to measure the extent of underreporting found that for every injury reported, about 4.3 injuries go unreported; however, most of the injuries that are not reported are minor (9). Reporting practices may also vary from school to school. These discrepancies can result in an injury problem being overlooked at a school or the employment of inappropriate remediation measures.

Most of what is known about the risk of intentional injury in schools is derived from voluntary, school-based surveys of particular behaviors, such as physical fighting and willingness to carry a weapon, or particular injuries or illnesses. Frequently, however, response rates are poor, and students do not report honestly. Administrators and school officials from major districts do not always respond to national surveys.

Health questionnaires are often given to patients or family members who must rely on their memory of the illness to describe symptoms. Such self-reporting involves subjective and selective recall about exposures and health effects (18). The National Health Interview Survey relies on parental recall of their children's illnesses. To overcome the problems of faulty recall, they return to the family every other week (3). This requires the careful analyst to look for additional evidence or supporting examples before drawing conclusions.

Even accounting for underreporting and self-reporting, analysts of injury and illness data must determine the extent to which the study can be representative of the larger population or only a narrow segment of it. Even well-designed studies can fall victim to what is termed "selection" bias, where an association is thought to exist but is in reality an artifact of the population being studied. In the case of schools, the finding of illness in certain schools may reflect underlying difficulties of a particular school or small group of schools—not schools at large. For example, a survey of schools with indoor air quality problems is not representative of air quality in schools generally but represents "problem schools," which suffer from actual or perceived elevated indoor air contaminants or other indoor air quality problems.

Uncertainty and Variability

Estimates of the health risks are both uncertain and variable. *Uncertainty* means that we do not yet know the true risk; uncertainty can be reduced through additional data or research. For example, uncertainty exists in estimates of injuries on school playgrounds because of underreporting. *Variability*, in contrast, means that the risk differs considerably from school to school or person to person; variability cannot be reduced, only better understood. Variability appears in estimates of the likelihood that any single smoker will develop lung cancer: some do, and some do not, based on a variety of individual factors that include age and genetics but may include other factors that are not now recognized.

Extrapolation

Extrapolation is most often seen as a problem in environmental health studies. The use of animal data requires extrapolating from animal results to human projections, and from very high exposures to low exposures. When human data are available, they are usually from studies of high levels of exposure, mostly in occupational settings. Analysts then have to extrapolate from the effects of high-level exposures to mostly healthy, working-age men in order to predict effects in young people of varying health characteristics in the school environment. The most prominent occupational-to-school risk extrapolations found in this study are those for lung cancers arising from asbestos or radon exposures. The data come from high-level occupational exposures of populations of men that included many smokers.

Extrapolations are not limited to the environmental health arena. For example, there are no school transportation injury data; thus, injury data reported for school-aged school bus occupants, pedestrians, and bicyclists are assumed to represent students on their way to and from school.

MOTIVATIONS FOR DATA COLLECTION AND ANALYSIS

A fundamental problem for everyone concerned about risks in schools is whether the available information is good enough to help make the decision to accept a risk or expend resources trying to reduce it. It is impossible to collect all the data that might be useful. Instead, analysis of the available data and careful thought about what kinds of data might alter an already-made or pending decision can guide the decision on what additional data to collect.

The surveys and studies that generate health and safety data are usually quite expensive and time-consuming and require considerable expertise to conduct. Decisions to expend those resources can be made for one or more specific reasons, and knowledge of the reasons can help in understanding how the surveys and studies were designed and by whom and the principle objectives of the research. These reasons can include legal requirements (e.g., federal, state, or local reporting laws), litigation, investigations of "rashes" or "outbreaks" of injuries or illnesses, or fear of adverse health effects. These motivations sometimes impugn the credibility of researchers, reducing the usefulness of their results.

Mandates

The most potent motivations for collecting health and safety data are laws that mandate reporting of various kinds. Illnesses and the potential for exposures to environmental toxics are subject to more mandated reporting requirements in schools than are injuries. On the federal level, the Federal Bureau of Investigation (FBI) requires reporting of homicides and suicides, but not in such a way that permits identification of those that occur in schools. Three agencies collect intentional school injury data for national surveys, but there are no mandated nationally reporting systems.

Some federal laws require either the reporting of illnesses and the potential for exposures or the identification of hazards. The Asbestos School

Hazard Abatement Act of 1985 and its 1990 reauthorization (ASHAA) require schools to inspect for asbestos. Both the Superfund Amendments and Reauthorization Act of 1986 and the Indoor Radon Abatement Act of 1988 directed the U.S. Environmental Protection Agency (EPA) to conduct surveys of radon concentrations in schools (as well as other buildings), and the school survey results were reported to Congress in 1993 (32). School are encouraged but not required, under the 1988 Lead Contamination Control Act, to test their drinking water and meet a recommended lead level.

Some states also have reporting requirements. Three—Hawaii, South Carolina, and Utah—have voluntary school injury reporting. Some states require reporting of school crimes, including those involving intentional injuries; the South Carolina legislature was the first to pass such legislation. Other state laws and initiatives trigger investigations or surveillance of environmental illness. California and Washington require the reporting of pesticide illness, including school exposures. South Carolina requires lead testing in day care facilities and foster homes as a condition of licensure. The New York City board of education monitors the physical appearance of all school buildings on an ongoing basis and presents its findings about such hazards as lead paint chips on an annual basis.

Fear and Litigation

Fear and concern can also motivate data collection, resulting in an ebb and flow over time. Urban violence has resulted in increased interest in weapons carrying, not only in big cities but in smaller communities as well. If concern about that wanes, fewer studies of weapons carrying can be expected. The installation of resilient pads covering the ground of some New York City playgrounds dramatically decreased injuries from falls, reducing the motivation for continued surveillance of such injuries. To a major extent, public perceptions of risk provide the motivation for data collection and studies, and that motivation is transmitted through legislation, legal actions, and public pressure.

Data collections and investigations are also performed in anticipation of possible litigation and as a response to pending litigation. Litigation against schools is increasing, particularly negligence cases (11). As a defensive measure, some schools attempt to keep records of injuries occurring on school grounds. However, unless there is an actual suit, these records are rarely tallied and analyzed, and thus are of no value in estimating injury risks. Lawsuits against schools for environmental exposures have led to the gathering of exposure data. A lawsuit filed against the state of Texas required various investigators to assess the presence and concentration of asbestos in the state schools (7). A lawsuit by a teachers' union forced California to investigate EMF exposures (5). Because large sums of money are often involved in litigation, researchers can obtain research funds to conduct studies they otherwise could not afford. However, they must maintain strict independence and follow scientific protocols to avoid perceptions of biased research, which damage the credibility of the results.

Credibility of Researchers, Bias, and Fraud

Researchers and investigators who collect health and safety data and conduct studies about risks can come to their tasks with or without vested interests. People who depend on those data and who disagree with them can accuse the researchers of bias or fraud, even if there is little evidence for the charges. The media can report those charges, giving them credibility, without any independent investigation.

Consider the situation when stakeholders in arguments about risk generate some of the data necessary for decisionmaking. They are tarred with bias no matter how honestly they do their work. On one side of the ideological spectrum, investigators may believe a particular agent or environment, such as a school setting, is responsible for adverse health effects and gather data to show an association between exposure and effect, with the objective of forcing government action or winning a lawsuit. On the other side, studies conducted or supported by manufacturers of a substance under suspicion or those responsible for releasing it into the environment, or by a school district that wants to avoid paying for risk removal, may be viewed skeptically, especially if they fail to show an association between exposure and illness.

Bias or prejudice can be knowing or unknowing, overt or covert, and it can be readily apparent or hidden from all but the most astute observer. Moreover, neither bias nor prejudice may play a role in data collection or study, but either one can be cited as a criticism by participants in a controversy who do not agree with the study results. The conventions of both science, which include publication of results and making data available to other researchers, and democracy, which include discussion, public accountability, and involvement of concerned parties, will not necessarily erase unwarranted charges or validate accurate ones. Nevertheless, they are the most effective tools for ensuring that data are as accurate as possible, that the methods used to collect the data are appropriate, and that the presentation of results is as free from bias as possible.

THE SIGNIFICANCE OF RISKS AND ESTIMATES

This study is intended to inform decisionmakers about the available information and its sources, and to provide some evaluation of the quality of that information. Deciding what to do, if anything, about any of these risks involves consideration of many more factors than are covered here—including fairness, public fears, cost, and feasibility of controlling the risk.

The results of available risk estimates can be compared against certain thresholds or standards as indicators of their significance. In discussions with experts and administrators who contributed data and information to this report, four general kinds of comparisons emerged: baselines, endpoints, school vs. nonschool risks, and risk thresholds.

Baselines

Baseline values are the normal background rates of the injuries or illnesses against which the risk from a particular hazard can be compared. Whether in comparing different risks or evaluating various policy options, baseline values are used as the expected numbers of illnesses and injuries. Officials use baselines to identify hazards by recording increased incidence or monitoring certain trends to see whether the measured rates are above or below the levels expected in a population. There are few established baselines, but the ones that exist are widely applied. Increases in influenza are identified by comparing current reported cases to historical averages; the District of Columbia's 11 percent decrease in homicides in 1994 is based on a comparison of the numbers of killings in 1992 and 1993.

A number of states have established or are attempting to establish a database to track trends in school injuries. More subtle baselines have been established as well. The CDC's Youth Risk Behavior System is creating baselines for behaviors that can forecast risks of intentional injuries in school.

Endpoints

This report uses the incidence of death, injury, or illness as a measure of risk. However, incidence only refers to the number and frequency and not the severity of risk, which—to a large extent—determines the risk's health impact. The impact of risks can be evaluated by considering their endpoints, as measured by the nature of the injury or illness. Endpoints can range from acute effects such as poisonings and broken bones to chronic effects including cancer and debilitating injuries that result in paralysis. Some endpoints—traumatic death, death from cancer, long-term mental or physical impairment—are far worse than others—a scrape or bruise, a 24-hour fever. Beyond such obvious differences, it is difficult to put endpoints on a comparative scale. The endpoints, or impacts, of illnesses and injuries can be distinctly different from each other, and the differences complicate comparisons of risks.

Even with related endpoints, comparisons remain complicated. Most significantly, methods for determining risks of the major risk factors differ: infectious diseases and injuries are counted and measured; illnesses from environmental hazards are estimated for some and counted for others. One endpoint used in this report common to both injury or illness is measuring the number of school days lost.

School and Nonschool Risks

Children and adolescents spend some time in school and a much greater proportion of their time elsewhere. One way to put school risks in perspective is to compare them to nonschool risks. This report, wherever possible, compared injuries and illnesses in school, where students spend about 12 percent of their total time, to injuries and illnesses in the nonschool environment, making allowances for the different times spent in the two environments.

In this report, safety is described in terms of relative risk between in-school and out-of-school. Such comparisons to other environments where children spend time may show that schools and school grounds offer a "safer" environment from certain risks, i.e., relative to out-of-school environments, in-school exposures to a potentially harmful situation for injury or illness may not be as great; conversely, in other situations, the risk is greater and hazards may be more prevalent in schools. Safety is a relative term since it is not a guarantee of a risk-free environment—violence even erupts in "safe cities" and on "safe streets" and in peaceful rural areas. Infections are spread in clean homes and schools and in hospitals despite expert, directed precautions. Nevertheless, comparisons serve to illuminate differences inherent in the various environments in which children learn, play, and reside.

Risk Thresholds for Intervention

Wherever possible, OTA presents baselines or nonschool comparisons and, in a few cases, regulatory exposure limits, all of which can serve as benchmarks to help determine whether interventions are warranted. This information comes from a variety of sources, including federal or state governments and other credible authorities. School-specific benchmarks are most useful, but few are available. More general comparisons, from nonschool situations, are best used with care, but they provide important information for decisionmaking. Federal, state, and local regulations for many environmental hazards specify certain thresholds that trigger actions to reduce or prevent exposure.

Few regulatory thresholds exist for infectious disease or injury hazards. The tolerable level for injuries varies by type of injury and from community to community. Certainly, some levels are unacceptable. They are, equally, undefined. Some injuries are of high incidence and low severity, others are of low incidence and high severity, and reactions to them often differ. For example, proper playground surfacing may not be installed until a large number of children suffer abrasions or broken fingers, but one homicide can trigger installation of metal detectors.

A large number of cases of common childhood diseases may not elicit medical attention, but outbreaks of illness from foodborne pathogens or with high severity, such as meningitis, can trigger further investigation and interventions to prevent disease spread. There are, however, no specified thresholds that require action. Also, reported environmental illnesses—such as complaints about indoor air quality problems—can trigger investigations. In this case, no threshold has to be crossed; a complaint is sufficient.

Asbestos is an example where the presence of a substance, without knowledge of its concentrations, is sufficient to trigger some forms of intervention. EPA, as mandated by Congress, requires visual inspections of schools for the presence of asbestos-containing materials. Airborne asbestos fibers are the hazard in schools, but EPA never established a level of airborne asbestos that was considered sufficiently high to require action or sufficiently low to ignore.

In other cases, numerical thresholds exist. EPA can require remediation actions when lead concentrations in drinking water exceed 20 parts per billion. EPA does not enforce a standard for radon in homes, schools, or other buildings.[3]

ROAD MAP TO THIS REPORT

The remainder of this report presents the data on hazards in the school environment that can adversely affect students' health and a chapter on how these data may be used. OTA separates the hazards based on their health effects, whether injuries or illnesses. Chapter 3 covers injuries to students in schools and the nature, incidence, and causes of injuries. Injury is broken down by intentional and unintentional injuries. Unintentional injuries are injuries from playgrounds, school athletics, and transportation to and from school. Intentional injuries include homicides, suicides, physical fighting, and assaults.

Chapter 4 examines student illnesses. The major school-related causes of illness identified in the report are environmental hazards and infectious diseases. Environmental hazards include toxic materials in the school environment, indoor air quality problems, and hazards arising from the location of the school. Infectious diseases arise from a number of pathogenic organisms and either occur with a high incidence on an endemic or seasonal basis, or they occur less frequently and primarily as outbreaks.

The final chapter discusses how the data presented in the report can be used by decisionmakers—from Congress to individual school boards—in setting priorities for improving school safety. A section of the chapter examines other attributes of risks, beyond the numbers of deaths, injuries, or illnesses, that can play an important role in decisionmaking. A final section explores comparative risk assessment, a process that can be used for comparing and ranking the diverse risks in the school environment.

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[3] EPA has proposed a standard for radon in water (30), but recommends that homeowners undertake mitigation efforts when the radon concentration is equal to or exceeds 4 pCi/L; its report of the survey of radon in schools (23) emphasized that concentration as a level of concern.

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Injury to Students in School 3

Injury is the leading cause of death and disability of children in the United States (54,101). School-aged children ages 17 and younger sustain about 16,614,000 injuries annually (67)[1] which often take a heavy physical, emotional, and financial toll on the children and their families. Children lose over 10 million school days each year due to injuries alone, an average of 22 lost school days per 100 students (8). However, students reduce their exposure to the most serious risks of injury for school-aged children simply by attending school because the leading causes of death and injury to children, such as motor vehicle-related injury, homicide, suicide, falls, and drowning (see figure 3-1), are more frequent outside of school. Nevertheless, a significant number of deaths and disabling injuries occur in the school environment.

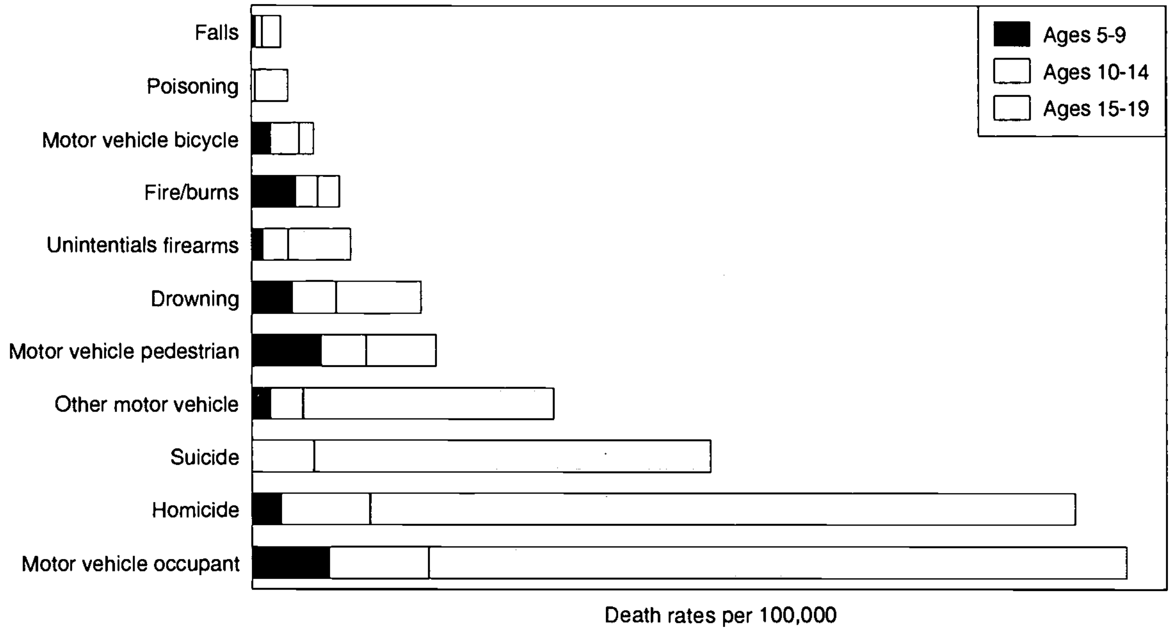
This chapter defines risks to students in schools by number and severity of injuries. An injury occurs from an "acute exposure to energy, such as heat, electricity or kinetic energy of a crash, fall, or bullet. Injury may also be caused by the sudden absence of essentials, such as heat or oxygen, as in the case of drowning" (54).

Risks of unintentional injury to students vary each school day: in their travel to school; in the controlled, supervised classroom environment; in physical activities in gymnasiums and athletic fields; the relatively unsupervised play during recess and lunch periods; and finally, on their return home (63). Demographic factors such as age, sex, race, economics, and geography influence the incidence and severity of injuries (4). The degree of risk to each student is a result of the interaction of many other factors, including the student's developmental stage, staff awareness and supervision, environment, equipment or products used at school (21), and school location.

This chapter presents information on school injuries based on "intent"—unintentional (accidental) and intentional (assaultive or suicidal).

[1] This estimate is based on data from the Child Health Supplement to the 1988 National Health Interview Survey (NHIS). Injury is defined by the NHIS as "a condition of the type that is classified according to the nature-of-injury code numbers (800-999) in the ninth revision of the International Classification of Diseases. In addition to fractures, lacerations, contusions, burns, and so forth, which are commonly thought of as injuries, this group of codes includes poisonings and impairments caused by accidents or nonaccidental violence" (8). "A person may sustain more than one injury in a single accident (for instance, a broken leg and laceration of the scalp), so the number of injury conditions may exceed the number of persons injured. Statistics of acute injury conditions include only injuries that involved medical attendance or at least a half day of restricted activity" (8).

FIGURE 3-1: Injury Death Rates, Children 5–19 years, 1992
(Rates are deaths per 100,000 population)



NOTE: Rates based on fewer than 20 deaths are not reliable.

SOURCE: National Center for Health Statistics, data from the National Vital Statistics System.

For a number of reasons, other reports have chosen to use the term "accidental injury" when reporting unintentional injuries. The term "unintentional injury," however, is more commonly used by experts in the injury prevention field because it connotes the ability to predict and prevent most of these injuries.[2] Intentional injury means the "threatened or actual use of physical force against oneself or an individual or group that either results, or is likely to result, in injury or death" (88). In this report, intentional injuries include interpersonal violence and suicidal behavior. Unintentional and intentional injuries differ in the type of injury that results, its severity, and the level of response or dread it engenders. Because of these differences, the types and quality of data collected for unintentional and intentional injuries also vary.

OTA surveyed the available injury data and examined three interrelated questions:

1. What school injury data currently exist?
2. What is the quality of the existing data?
3. Given that most estimates are uncertain and variable, what additional data are needed to help decisionmakers?

To answer these questions, this chapter reviews and comments on the available data concerning injuries occurring in the school environment. As discussed in chapter 2, the types of data

[2] As explained by the Centers for Disease Control and Prevention (CDC), "[i]njuries are mistakenly referred to as 'accidents' because they occur suddenly and are seen as unpredictable and uncontrollable. In particular, parents often believe that 'accidents' will not happen to their child because the child is well supervised. Injury prevention in children is much more than a question of supervision; injuries, like disease, occur in highly predictable patterns and are controllable."

included are: 1) surveillance;[3] 2) survey; 3) epidemiological; and 4) anecdotal. This chapter identifies the data sources of school injury data and assesses their strengths and weaknesses.

Data on unintentional and intentional injuries in schools are widely dispersed. While some national and state estimates of both unintentional and intentional school injuries are available, the databases either do not clearly distinguish between intentional and unintentional injuries or collect information on one or the other. A study based on the Child Health Supplement to the 1988 National Health Interview Survey (NHIS), which provides national estimates of nonfatal childhood injuries, is the one study to analyze national data by school as a location of injury (67). While not limited to the school environment, national databases of playground, athletics, and school bus-related crash injuries provide data used to calculate or estimate the number of school-related unintentional injuries associated with these activities. There are also national estimates of the number of homicides and suicides in the school environment as well as national and local self-report surveys on physical fighting and weapon carrying that provide additional data on nonfatal intentional injuries.

State and epidemiological studies rely on school reports for estimates of school injuries. Epidemiological studies provide a more detailed picture of injury incidence. Because of diverse reporting, underreporting, and inadequate reporting, school injury trends are difficult to characterize. Often within single school districts certain schools report injuries more conscientiously than others. The absence of standardized definitions of reportable injuries among the states and school districts limits comparisons of data. Injury data regularly lack elemental aspects of injuries such as the location, characteristics, causative contributors, socioeconomic, and demographic factors, such as gender and race, particularly for nonfatal events (54). The absence of this information prevents the determination of the circumstances of injury.

Assessment of the available school injury data identifies the need for additional or better quality data to aid decisionmaking. Quality data can turn public attention and possible resources from well-publicized but infrequent occurrences toward more common injuries that represent a greater public health problem. Data collection and analysis can uncover school injury problems or reveal more about a problem already suspected. Implicit in this process is that it can eventually lead to the overall reduction of school injuries.

UNINTENTIONAL INJURY

Unintentional injuries are recognized as a leading cause of childhood mortality and morbidity in the United States. One of the health objectives set forth in *Healthy People 2000: National Health Promotion and Disease Prevention Objectives*[4] is to "provide academic instruction on injury prevention and control, preferably as part of quality school health education, in at least 50 percent of the school systems (grades K through 12)" (87). Compared to unintentional injuries in general, little public attention is given to those occurring in the school environment except in the aftermath of a particularly tragic incident, such as a fatal school bus crash or football injury. Injury deaths, however, are not always representative of injury incidence at school.

Given the time students spend at school and the variety of activities they engage in, the school environment presents many opportunities for injury. For school-aged children, epidemiological studies estimate that 10 to 25 percent of their

[3] Surveillance data has been defined as the "ongoing and systematic collection, analysis, and interpretation of health data in the process of describing and monitoring a health event. This information is used for planning, implementing, and evaluating public health interventions and programs" (42).

[4] Healthy People 2000 is a U.S. Public Health Service plan that developed health objectives designed to reduce preventable death, disease, and disability by the year 2000. Unintentional injury is a priority area targeted for specific reductions in mortality and morbidity.

injuries occur in the school environment (66).[5] Although many of these injuries are minor cuts and bruises that heal quickly, significant numbers are quite serious, resulting in absence from school, restricted activity, hospitalization, disability, and death.

Incidence of injury of students is a function of the type of activities in which they participate and their developmental stage (21). For example, elementary school students are most likely to be injured on the playground, while secondary school students are most likely to be injured playing sports. Their developmental stage also affects their ability to recover from injury. The healing processes of school-aged children are remarkably different from adults because they are still growing (6).

Activities at school differ from those of children and adolescents outside the school. Accordingly, it is essential to recognize patterns of frequency and severity specifically related to school injuries. Students' activities during the day are, for the most part, supervised and restricted to relatively non-risky behavior. The leading causes of childhood unintentional fatal injuries, including motor vehicle crashes, drowning, and fires (see figure 3-1), are more likely to occur outside of school. Thus, the nature of injuries and the focus of prevention efforts directed at school injuries can differ from childhood injuries at other locations. Knowledge of the circumstances involved in such unintentional injuries is important for the development of prevention and control efforts that adequately address the potential risks to students in the school environment.

Due to their frequency and severity, playground and athletic injuries generate considerably more data than other school-related injuries. Accordingly, a separate discussion of playground and athletic injuries follows the general discussion of school-related injuries below. Injuries sustained on the journey to and from school are also discussed separately because they involve different data sources.

Sources and Limitations of School-Related Injury Data

Sources of data on the incidence and prevalence of unintentional injuries in the school environment are:

1) National sources:
- National Center for Health Statistics, U.S. Department of Health and Human Services;
- Centers for Disease Control and Prevention (CDC), U.S. Department of Health and Human Services;
- National Highway Traffic Safety Administration (NHTSA), U.S. Department of Transportation;
- Consumer Products Safety Commission's (CPSC) National Electronic Injury Surveillance System (NEISS);
- National Safety Council (NSC); and
- National Pediatric Trauma Registry (NPTR).

2) State studies and surveys.

3) Epidemiological studies.

National Sources of Data on Unintentional Injuries in Schools

While OTA found no continuous national surveillance system that supplies comprehensive information about school-related unintentional injuries, national databases collect general information relating to childhood injury (54). There are five major national types of unintentional school-related injury data: death certificates, hospital discharge abstracts, hospital emergency room reports, national health survey data, and traffic accident data. These sources have their various advantages and disadvantages, as explained in box 3-1. National data can provide a perspective of injuries and allow for comparisons to local injury data. For the most part, however, the existing national data sources focus on particular problems that include school injuries, but rarely distinguish them from non-school injuries. Even when differentiated, school injuries may include many types of schools, such as colleges and vocational schools.

[5] The NHIS reports that school-aged children sustained 13 million injuries in 1992.

BOX 3-1: National Sources of Data on Unintentional Injuries in School

Mortality data

The **National Center for Health Statistics** (NCHS) of the U.S. Department of Health and Human Services (DHHS) is the primary source of fatality data; it collects mortality statistics from all 50 states. Fatality data are collected from death certificates, which include information on the cause of death. However, the national report is usually published about three years after the death occurred. The coding of fatal injuries is based on the apparent intent of the persons involved—unintentional, homicide, or suicide (NRC, 1985). Additional coding as to circumstances and location is limited; there is no categorization of the school locale on hospital injury coding forms or death certificates. Also there is no standard system among the states for filling out death certificates, which are often completed without an autopsy or before one can establish the cause of death. Moreover, fatality data may overstate the unintentional fatalities if some intentional injuries, such as suicides, are incorrectly reported. Or conversely, the unintentional fatality data may be understated if some intentional deaths, as a result of child abuse, for example, are reported as unintentional. While these statistics are useful in monitoring national fatality trends, without the reporting of school as a location there is not enough detail to determine fatality trends occurring at schools.

The **National Highway Traffic Safety Administration** (NHTSA) of the U.S. Department of Transportation compiles and analyzes mortality data on school bus-related accidents and on pedestrian and bicyclist mortality for the school-aged population. NHTSA's Fatal Accident Reporting System (FARS) database, established in 1975, compiles information relating to fatal motor vehicle crashes from state agencies. FARS sources include police accident reports, death certificates, and coroner or medical examiner reports. Data include geographic details, roadway and other conditions, information about the driver of the vehicle, and on fatally and nonfatally injured persons involved (including passengers, pedestrians, and others). These data do not distinguish whether travel was school-related.

Morbidity data

DHHS's **National Health Interview Survey** (NHIS) collects data on nonfatal injuries based on household interviews of the civilian noninstitutionalized population. In 1992, 49,401 households containing 128,412 persons were sampled; 96 percent of these households were interviewed.[a] While the NHIS includes "school" as a location for injury, the data are not analyzed regularly or published by school location. Scheidt et al. studied the Child Health Supplement to the 1988 National Health Interview survey to derive national estimates of nonfatal school injuries. The study included a breakdown of the location of injury, including school; the data are not routinely analyzed by school as a location of injury. School as a "place of accident" is defined in the NHIS to include "all accidents occurring in school buildings or on the premises. This classification includes elementary schools, high schools, colleges, and trade and business schools." Thus, the injuries incurred by adults as well as by students K through 12 are included. By limiting the study to persons aged 17 and younger, Scheidt et al. resolved this problem—previous school data were not analyzed by age.

The **U.S. Consumer Product Safety Commission** (CPSC) maintains the National Injury Information Clearinghouse, another source of data on nonfatal injury. Its database includes: death certificate data, the National Electronic Injury Surveillance System (NEISS), accident investigations, consumer complaints, and other injury reports. The NEISS database, the primary CPSC data source for this OTA report, collects injury data from a sample of 91 hospital emergency rooms located throughout the United States. The small sample number precludes determination of regional trends. CPSC data are by definition confined to consumer product-related injuries, thereby limiting the database's usefulness for purposes of this report. For example, the NEISS database does not record all playground and sports-related injuries; it is limited to injuries relating to playground *equipment* and sports *equipment*. Thus, reports from NEISS reflect national estimates of persons with injuries associated with products under CPSC's jurisdiction treated in emergency rooms. CPSC does not have jurisdiction over firearms and motor vehicles.

(continued)

BOX 3-1: National Sources of Data on Unintentional Injuries in School (Cont'd.)

NEISS collects injury data by location categories, including school, but does not analyze data using school as a category. Again, school includes all types—for example, elementary, secondary, vocational, college, and graduate school. Restricting the analysis of injuries to ages 5 to 18 would theoretically restrict the data to elementary and secondary students. CPSC produces such data but does not analyze it. NEISS is capable of discovering national injury trends in a timely fashion, allowing for preventive action. CPSC also publishes safety alerts concerning consumer products, which include equipment used in schools.

Transportation-related nonfatal injury data are from **NHTSA's** General Estimate System (GES), which is a nationally representative probability sample selected from police reports of motor vehicle crashes. NHTSA produces data related to school bus accidents, as well as pedestrian and bicyclist morbidity data. GES data are from a nationally representative probability sample selected from police reports of motor vehicle crashes.

OTA identified two additional national sources of school-related injury data: 1) the **National Safety Council** (NSC) and 2) the **National Pediatric Trauma Registry** (NPTR). NSC collected data on "student accidents" from 7,500 responding school jurisdictions. Accidents were defined as causing the loss of one-half day or more of school time or activity during non-school time and/or any property damage as a result of a school jurisdictional accident. NSC reports the number of injuries in terms of student days rather than student years, which makes it difficult to compare injury rates with other studies, almost all of which are reported in years. Moreover, NSC figures are outdated—the last edition of its *Accident Facts* to include school injuries was published in 1987 and the reported data was collected in academic years 1984–85 and 1985–86.

NPTR data include information from 61 hospitals located in 28 states, Puerto Rico, and Ontario, Canada. From December 1987 to February 1993, 871 cases of school-related injuries of students aged 5 to 19 were recorded in the Registry. In an epidemiological study, Gallagher et al. analyzed 907 school injury cases to assess the causes and consequences of serious injuries occurring among students (Gallagher, 1994). The data evaluated included 19-year-olds, but it was unclear whether "school" was limited to high schools or included college campuses. Since trauma center data are not population-based and catalogue only a few of the most serious cases, conclusions cannot be generalized to the less seriously injured or non-injured school population (NRC, 1985). Moreover, trauma centers receive referrals from other hospitals and many trauma centers specialize in particular types of injuries. Nevertheless, these valuable data illustrate the types and distribution of severe injuries suffered by children and adolescents at school.

[a]The 1992 questionnaire enabled identification of out-of-school youth (aged 12-21 years) by inquiring whether they were either now going to school or on vacation from school. The results will be used in the Youth Risk Behavior Survey.

SOURCES: Office of Technology Assessment, 1995. National Research Council, Commission on Life Sciences, Committee on Trauma Research & Institute of Medicine, *Injury in America: A Continuing Public Health Problem* (Washington, DC: National Academy Press, 1985); Gallagher, S., Bowdler, M., and Di Scala, C., unpublished data on the cause of severe injuries at school: Results of an Analysis of 907 Severe School Injuries Reported to the National Pediatric Trauma Registry, Newton, MA, 1994.

State Sources of Data on Unintentional Injuries in Schools

No state currently requires mandatory reporting of school-related injuries to the state departments of education or health. OTA identified four states (Arizona, Hawaii, South Carolina, and Utah) that maintain school injury databases, but all four depend on voluntary reporting. These databases are described in box 3-2.

Although few states require reporting at the state level, most schools and school districts keep injury records. For example, Miami, Florida's

BOX 3-2: State Sources of Data on Unintentional Injuries in School

OTA indentified only four states with voluntary state-wide reporting requirements (Arizona, Hawaii, South Carolina, and Utah). In the absence of national reporting, voluntary or otherwise, there is no uniformity in reporting school injuries among states that do compile injury data. Each state uses diferent reporting methods and criteria. Arizona and Utah have computerized forms, which greatly facilitate data collection. Other states have completed studies but currently do not have an ongoing surveillance program (Kansas and Washington) or are just beginning to implement ongoing school injury surveillance systems (Michigan, Minnesota, and Washington). Although Arizona and Michigan have drawn on Utah's experience, for the most part there is little coordination among state departments surveying school injuries; in some cases, states were not aware of other efforts. Some states, such as Massachusetts, have injury surveillance programs from which school injury data can be culled.

Arizona Department of Health Services

In 1991, Arizona instituted the Arizona Injury Surveillance Program. The first reporting year was limited to playground and athletics injuries. The study evaluated 212 elementary schools including 122,056 students in grades K–8, representing 29 percent of the school population. Student health personnel were required to complete a report form when an injured student 1) was sent home, 2) was sent to a physician, 3) was transported or admitted to a hospital, or 4) required restricted activity. The second year's data will be published in early 1995 and the third year data are being analyzed. In 1993, with input from school districts and the main school insurance companies, Arizona officials developed a scannable report form. The front of the form is for recording injury information and the back now includes information for insurance purposes. The program will soon include all school injuries and all grades, starting at preschool and daycare and going through high school. The program will soon include more schools and entire districts. An Early Childhood/School Injury Task Force meets quarterly to determine the direction of the program.

Hawaii Department of Health

In 1984, Taketa attempted a statewide analysis of school injury data collected by the Hawaii Departments of Education and Health. The study evaluated 204 of Hawaii's 224 public schools by collecting Student Accident Report Forms completed by school nurses during the 1981-82 academic year. However, the information varied considerably, impeding efforts to identify particular risks. The Hawaii Department of Education's most recent data are for 1989-90. The data are compromised by the uncertainty of the percentage of the school population included in the report. The data are presented only in terms of location, activity, and nature of injury; not by gender, age, or grade.

Kansas Department of Health

Until 1981, the Kansas Department of Health and Environment biannually published a Student Accident Report. The 1981 report, the 32nd edition, summarized the nonfatal student accidents occurring in Kansas during the 1979–80 and 1980–81 school years. Injuries reported to the department involved those severe enough to cause a student absence of half a day or more from school or to require a doctor's attention. Study authors noted that reporting was incomplete. Significantly, the study was able to track trends over a 25-year period, particularly increases in rates and percentages over the years.

Minnesota Department of Education

In 1989, the Minnesota Department of Education first administered the Minnesota Student Survey with the aim of furthering the understanding of student behaviors and attitudes. The survey was given to students in the 6th, 9th and 12th grades. The only relevant injury questions ask whether an injury occurred at "school not sports" and at "school sports." While the overall injury numbers are useful for comparing the two categories of injuries, the survey provides no insight into the factors causing student injury.

(continued)

BOX 3-2: State Sources of Data on Unintentional Injuries in School (Cont'd.)

South Carolina Department of Health

The South Carolina Department of Health administers the Annual School Health Nursing Survey to compile data about the health status of children in schools. Surveys were distributed to head nurses in 91 school districts; however, not all schools have a nurse. In the two years the report has been completed, school district response rates were 44 and 45 percent. In the 1992–93 school year, this represented about half of the school districts, 69 percent of the 300 school nurses and 60 percent of the students (342,587 students). Data are analyzed to assist those responsible for school health and policy decisions at the state and local level. School nurses in South Carolina have used this survey to identify injury problems and to coordinate and develop injury intervention programs. In fact, in 1992–93 there was a reported decrease in the total number of injuries, despite a fourfold increase in reporting. The 1992-93 report attributes the reduction to data collection efforts that have been translated into local school prevention and intervention efforts.

Utah Department of Health

In 1984, Utah established a voluntary reporting system in which school districts use the Department of Health's student accident report form to report injury information. Since that year, the Department of Health has collected statewide information on injuries sustained by students in schools.[a] Its computerized database is the most comprehensive statewide school injury data source in the United States. Reportable injuries are defined as those severe enough to cause school absence of at least a half day or to warrant medical attention and treatment. To increase the accuracy of description, the form has been revised a number of times in response to problems identified by schools using the form. Participation of the 40 state school districts has progressed to 100 percent since the database's inception. As a result of increased participation and reporting refinements, data collected since the 1988-89 academic year are the most reliable. Nonetheless, as with all school-based injury data, incidents are probably underreported. For example, in 1988–89, the incidence in grades K–6 was 1.7 injuries per 100 students, which increased to 2.1 per 100 students by 1991–92. The Utah Department of Health does not attribute this increase to an overall increase in incidence but to an increase in reporting by school districts. Further analysis of this data by individual grade, if possible, would more accurately define incidence grade peaks and indicate when a student is most at risk from a particular hazard.[b] Similarly, analysis by grade and sex would yield significant insight into the occurrence of school injuries. The Utah data are not contained in a formal report; rather, they were amassed by the Department of Health and presented by category for the two grade divisions, K–6 and 7–12, for each academic year from 1988–89 to 1991–92.

The Utah State Department of Health and Utah State University used the data to identify playgrounds as the leading cause of school injuries at schools and to develop the 1988 publication "Playground Perspectives: A Curriculum Guide for Promoting Playground Safety."

Two additional school injury studies were sponsored by states. These are epidemiological studies; they were limited to specific locations rather than statewide.

(continued)

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BOX 3-2: State Sources of Data on Unintentional Injuries in School (Cont'd.)

Massachusetts Statewide Comprehensive Injury Prevention Program

The Massachusetts Department of Public Health established the population-based Massachusetts Statewide Comprehensive Injury Prevention Program (SCIPP), a hospital-based injury surveillance system (Passmore et al., 1989). The advantage of hospital-based over school-based data is that the diagnosis and circumstances relating to the incident are more accurate and reliable. As with all hospital-based data, however, only the most severe cases are seen and selection biases are inevitable. The SCIPP system compiled data on injuries among 86,876 children and adolescents (0–19 years) living in 14 communities from September 1979 to August 1982. Twenty-three participating hospitals accounted for an estimated 93 percent of all pediatric discharges. Since the information is hospital-based, visits to doctor's offices, clinics, health maintenance organizations, or dentist's offices were not included. Passmore and Gallagher analyzed the SCIPP database to determine the incidence of school injuries in a Massachusetts community. This study is particularly important because the authors compare school and out-of-school injury incidence data.

Washington Department of Health

The Washington State Department of Health completed a two school-year study in 1986-87 and 1987–88, *The School Injury Surveillance Project: Results and Recommendations*, of a single school district as a pilot test program. The aim was to test the efficacy of school injury surveillance, with the ultimate goal of identifying potential prevention and investigation priorities. The district studied the Clover Park school district, which had a school-aged population of 12,781 in 1986–87. Injury reports were completed by school nurses and given to district risk managers to pass to the Department of Health. School nurses were to report injuries: 1) that were severe enough for the child to be sent home, including unsuccessful attempts to send the child home; 2) that required a physician's care and/or major first-aid treatment; or 3) that occurred during athletic activities and restricted competitive sports, competition, or practice for two or more days, including all joint injuries, fractures, head and neck injuries, and internal injuries.

[a]Utah's computerized school injury database was used for the article by Sosin et al. (1993) on surface-specific falls on Utah school playgrounds.

[b]Enrollment data for grades 7–12 were not readily available; therefore, rates could not be determined. The percentages of injuries in grades K–6 can be compared to the those in grades 7–12 to contrast the injury experience of the two groups.

SOURCES: Arizona Department of Health Service, Community and Family Health Services, Office of Women's and Children's Health, *A Study of the Nature, Incidence, and Consequences of Elementary School Playground-related Injuries* (Arizona, 1993); C. Cazier, Project Director for Family Health Services, Utah Department of Health, Salt Lake City, UT, personal communication, 1994; S.S. Gallagher and K. Finison, "The Incidence of Injuries Among 87,000 Massachusetts Children and Adolescents: Results of the 1980–81 Statewide Childhood Injury Prevention Program Surveillance System," *Am J. Public Health* 74:1340–1347, 1984; Kansas Department of Health and Environment, *Athletic Injuries in Kansas Secondary Schools 1990–91*, unpublished report (Topeka, KS: 1992); South Carolina Department of Health & Environmental Control, Division of Children's Health, *Annual School Nurse Survey 1993*, 1994; Utah Department of Health, Division of Family Health Services, Student Injury Report Database 1988–1992; S. Taketa, "Student Accidents in Hawaii's Public Schools," *Journal of School Health* 54:208–209, 1984; Washington State Department of Health, Office of Community Environmental Health Programs, *The School Injury Surveillance Project: Results and Recommendations* (Olympia, WA: 1990).

Dade County Public Schools maintains unintentional injury information annually (23). While some schools maintain records as part of their state's voluntary school injury reporting systems, many maintain injury records for liability purposes (28). The state departments of education or health rarely collect, tally, or analyze injury reports, and often the data on the local level are not computerized, making it difficult to retrieve information. In addition, such reporting is conducted through school districts and, therefore, evaluates only public schools. Injury data collected by private schools are not readily accessible or collected in any systematic manner; thus, comparisons of injury rates in private versus public schools cannot be made.

Epidemiological Studies on Unintentional Injuries in Schools

Epidemiological studies and state surveillance data complement each other. Although state surveillance data are better for identification of particular injury problems, epidemiological studies allow for more detailed analysis of a suspected problem. The five most prominent epidemiological studies found by OTA are presented in table 3-1. Despite the advantages, the available epidemiological studies have numerous drawbacks and methodological problems.

As with most epidemiological data, the available studies are narrowly focused on a small number of school districts, which prevents the determination of regional trends. It is apparent, however, that student populations and injury risks vary widely from school district to school district. Moreover, the focus on injuries occurring at schools does not inform about schools as a source of injury relative to other locations. The lack of standardization of what constitutes a reportable injury and what qualifies as a serious or severe injury across epidemiological studies hinders their comparability. Moreover, four out of the five studies are over 10 years old. The studies used varying reporting categories. For instance, some reported cause of injury by location, others by activity. Most studies define a reportable injury as one that causes the student to restrict school activity for at least half a day, but this criterion may select against late-afternoon injuries. Nevertheless, to the extent that the results of these studies are consistent, they indicate general characteristics of school injury incidence.

These studies draw from school-based, parent-based, and/or hospital-based reports. Of these, school-based reports collected from school districts are the primary source of data used by state surveillance systems and epidemiological studies. Parent-based reports complement school-based reports to assist in determining the accuracy of school-based reporting. Hospital-based reporting provides more comprehensive case information, but only for the most serious injuries.

Most state and epidemiological school-related data differ from national data in that they rely almost entirely on school-based reporting. School-based reporting generally involves completion of an injury report by a teacher, coach, administrator, or other staff member. In most cases, however, the forms are kept at school or a copy is sent to the school district office. Only four states actually collect and tabulate the number of injuries. The primary advantage of school-based data is that it theoretically captures all injuries that occur at school, regardless of the treatment. Moreover, school-based data is local. Decisionmakers at the local level can use the data to verify the actuality of an injury problem before committing scarce resources to a local injury control program.

Methodological concerns common to epidemiological and surveillance data are inherent in school-based reports. Such concerns include underreporting of both minor and serious injuries (13,103), and inconsistent definitions of injury and the school environment. Reporting practices may also vary significantly from school to school. The lack of standardized reporting for school-related injuries compromises the reliability of data. Although underreporting and inconsistent reporting among schools undermine the completeness of the data, school-based data are the most comprehensive and accurate data available.

TABLE 3-1: School Injury Epidemiological Studies

	Lenaway et al. (1992)	Boyce et al. (1984a)	Sheps & Evans (1987)	Feldman et al. (1983)	Taketa (1984)
Years analyzed	1988–1989	1980–1983	1981–1983	1981–1982	1981–1982
Site	Boulder, CO	Tucson, AZ	Vancouver, BC	Hamilton, Wentworth, Ont.	Hawaii
No. of schools	9	96	108	212	204
Grades	K–12	K–12	K–12	K–12	K–12
Student population	5,518	55,000	53,000	83,692	157,000
Data collection	Prospective	Prospective	Retrospective	Prospective	Retrospective
Definition: reportable injury	Student accident report forms completed by adult administering first aid (i.e., teacher, nurse or coach). Reportable injuries were those: "requiring medical or dental attention, head injuries necessitating student dismissal to home and those with persistent symptoms beyond a two hour observation period, poisoning, suspected fractures, human bites, puncture wounds, and injuries sustained from fighting or equipment failure"	Injury must meet one of the following criteria: (1) required a physician's care and/or major first aid; (2) resulted in an absence from school; or (3) resulted in restricted participation in competitive sports	If a child sustains or requires: "all head injuries, suspected or definite fractures, and ambulance or inhaler, referral to a physician or dentist, sutures or a foreign body in the eye"	Decision as to reportability "made by school principal, consistent with his interpretation of the school board's policy"	"Any accident which happens at school, or at a school sponsored activity, on or off campus, which (1) interrupts the students' normal or expected activity for that period to any significant degree, (2) causes any property damages or losses of more than $5 in estimated replacement cost and/or (3) can generate a litigation on behalf of the injured"
Incidence per 100 student years	9.2	4.9	2.8	5.4	1.7

(continued)

TABLE 3-1: School Injury Epidemiological Studies (Cont'd.)

Definition: severe injury	*	Amputations, third-degree burns, concussions, crush wounds, fractures, multiple injuries	Fractures, loss of consciousness, bums, whiplash, open wounds, foreign body in eye	Fractures, loss of consciousness, dislocations, sprains, tom ligaments and cartilage, chipped/broken teeth, internal injury	"Most severe...foreign bodies in the eye and fractures"
Percentage of injuries that were serious or severe	—	18%	35% elementary 39% secondary	28.6%	—

* no definition of severe or serious

SOURCE: Office of Technology Assessment, 1995, adapted from R.R. Gratz and K. Finison, "School Injuries: What We Know, What We Need," *Pediatric Health Care* 6:256–262, 1992; Lenaway, D.D., et al., "The Epidemiology of School Related Injuries: New Perspectives," *Am J Prev Med* 8(3):193–198, 1992.

A study designed to determine the extent of underreporting (103) of injuries in school-based reporting found about a fourfold difference: 24.0 injuries occurring per 100 students compared to 5.4 injuries reported, indicating that for every injury reported about 3.4 go undetected. Most of the unreported injuries appeared to be minor, while serious injuries were more likely to be routinely reported. Serious injuries were underreported by a factor of two, while minor injuries were underreported by a factor of five (27).

The study also contrasted parent and school reports of injury; parents reported three times as many school-related injuries (15.3 injuries per 100 student years) as schools did.[6] In terms of serious injuries, parents reported close to 30 percent of the total injuries as serious (19.5 percent elementary and 45.5 percent secondary school), in contrast to 13 percent categorized as such by schools (37). While the accuracy of the parental reports is unknown, the study concluded that estimates of the number and severity of injuries by educational authorities should not be relied on as the sole source for accurate injury information.

Hospital-based reporting, an alternative to school-based reporting, is generally more accurate and reliable than school-based reporting because health professionals diagnose the injury. Moreover, hospital records contain more detailed information about the circumstances of the injury and the final disposition of the case (13). In the context of school injuries, however, hospital-based data only represents the most severe injuries and does not include those untreated or treated by a school nurse, at home, or at a doctor's office. Also, hospital admissions may not be reflective of the distribution of injury, because selection biases such as bed supply and social class affect admission for all but the most severe injuries.

Hospital-based data are also problematic in that E-coding, the current system for classifying and coding cause of death and nonfatal injury, does not permit adequate description of activities surrounding the incident. E-coding, which codes for the external cause of injury, is part of the injury classification established by the World Health Organization and used with the International Classification of Disease (ICD) (86). Hospitals and vital statistics recordkeeping sometimes use the ICD, in its ninth revision, to explain how and where an injury occurred. Currently, there is not a national requirement for hospitals to record E-codes on injury records, with one exception (14).[7] In 1994, however, thirteen states had mandated E-coding of hospital records. As more states use E-coding, the data will improve; currently, however, the quality of the morbidity data is uneven. OTA concludes that mandatory use of E-codes for injuries and inclusion of school as a location classification would provide invaluable information for the study of nonfatal school injuries.

Incidence and Distribution of School-Related Injuries

Incidence

Scheidt et al. estimate that 16,614,000[8] injuries are sustained by children ages 17 and under in the United States annually; thus, medically attended injuries occur in at least 25 percent of children each year. Of those, it is estimated that approximately 3 million injuries occurred at school. Authors of the epidemiological studies estimate that 10 to 25 percent of injuries to the school-aged population occur at school (66). Epi-

[6] As part of a random sample, parents of about 200 children attending schools were surveyed over 10 months and asked if the student had sustained any school-related injuries during the previous month and, if so, the numbers, types, and treatment of injuries. Parent survey questionnaires were mailed at the beginning of the each month. If after three weeks the questionnaire was not returned, the parents were contacted by phone when possible. About 53 percent of these surveys were returned by mail and 32 percent were completed over the phone.

[7] E-code recording is required in those cases "where drugs or medicinal and biological substances caused an adverse effect in therapeutic use" (14).

[8] This estimate includes only those injuries involving medical attendance or at least half a day of restricted activity.

demiological studies are likely to include more injuries than national estimates, the excess attributable primarily to minor injuries.

Injury rates from school-related injury studies vary and are likely to underrepresent the number of actual injuries because of underreporting in the routine surveillance and reporting of injuries at schools (35). The variations may also be attributed to one or more of the following: 1) inconsistent case definitions of injury; 2) reporting methods (e.g., school-based as opposed to hospital-based reporting); 3) inconsistent reporting among study schools; 4) natural variability among student populations; and 5) implementation of school-based injury prevention programs.[9] The reporting methods also affect the number of injuries reported. For instance, prospective studies reported higher rates of injuries than retrospective studies (35).

In-School and Out-of-School Incidence

The NHIS reported 28.6 injuries per 100 school-aged children in 1992 (8). Similarly, based on 1988 NHIS data, the Scheidt study revealed an injury rate of 27.0 per 100 children. Population based studies are in close agreement—the Massachusetts Statewide Comprehensive Injury Prevention Program (SCIPP) data show about 24 injuries per 100 children or adolescents ages 6 to 19 (30), and a Puget Sound, Washington HMO population study show about 25 injuries per 100 children, ages 19 and under[10] (66). As shown in table 3-1, the rates of injury in schools found by epidemiological studies range from 1.7 to 9.2 per 100 students.[11] Considering the shorter time spent in school, about 12 percent of a child's year and about 15 to 20 percent of their waking hours annually, the data suggest that the number of school injuries may be about the same or slightly higher than out-of-school injuries. However, the majority of school-related injuries are minor and result in fewer hospitalizations than injuries sustained outside the school environment, and fatal injuries are relatively rare in the school environment (63).

Age-Related and Gender-Related Incidence

Incidence and characteristics of injuries correlate strongly with age and gender. Elementary students incur more injuries than secondary students, but the difference is primarily due to minor injuries. However, Feldman et al. identified a "small but statistically significant" difference between the rate of serious injury among elementary (1.6 injuries/100 students) and secondary (1.3/100) students and concluded that younger students sustained more severe injuries than older ones. Scheidt et al. found that adolescents aged 14 to 17 were at greater risk of injury at school than other students. Epidemiological studies, however, disclose that students aged 10 to 14, or in grades 6 to 8, appear to be at increased risk of injury (10,27,43,69,73). Feldman et al. explained the incidence crest as the effect of increased activities coupled with the onset of puberty. Growth of students in the 6th to 8th grades is characterized by rapid increase in body size, muscle mass, and strength, and consequently termed the "clumsy age" (27).[12] The 10 to 14 age group may also be at greater risk of serious or severe injury. The NPTR study found that 44 percent of hospitalized students were ages 10 to 14.

[9] Some injury investigators have suggested that injury rates among children may be inflated by a small number of children that suffer a large number of injuries (12). Studies found little evidence to support the accident-prone child notion (12, 27). Although the number of students with recurrent injuries are slightly higher than the rate expected by chance, the overall incidence rates were not greatly influenced.

[10] The study identified injuries of the 8,603 children, ages 0-19, enrolled with an HMO and treated in an HMO clinic, ER, or hospital. It was performed over a one-year period in 1985-86 (66).

[11] Studies of school-related injury outside North America report much lower rates. For example, Pagano et al. (1987) evaluated the student population in Milan, Italy, and found an average annual rate of 1.44 injuries per 100 students (62). Similarly, a study of primary and secondary students in West Lothian, Scotland, disclosed an injury rate of 2.6 per 100 students—3.7/100 for primary students and 1.9/100 for secondary students (11).

[12] However, one population-based study demonstrated injury peaks at ages 14-15, normally associated with 9th grade (63).

While playground and athletics (including both physical education and organized sports) account for the overall highest injury rates in school, distribution of these injuries changes over time due to students' development of physical skill, strength, size, judgment, balance, and experience with hazards (63). The rates of playground injuries decrease as elementary school children mature, while the rates of athletic injuries increase steadily through middle/junior high school to high school.

Across studies and grade levels, injuries occurred nearly twice as often to males than females and the difference was even more pronounced in adolescents (63,67). Minor injuries, rather than severe ones, constituted the difference between the genders (27). In a study designed to determine incidence of underreporting in schools, Woodward et al. found that girls' minor injuries were underreported more routinely (103). Most studies found little difference in gender rates for serious or severe injuries. One exception was the NPTR study of hospitalizations resulting from school injuries—it found a male to female ratio of 2:1. Regardless, the gender gap for overall injuries increases with age. The disproportionate increase in injuries to boys may be accounted for by the greater participation of boys in sports and also the type of sports played by boys.

Predictive Factors

Review of the effects of demographic and social factors, type of school, condition of school buildings, and the availability of health care at schools on injury incidence in schools is meager. With few exceptions, school injury studies have not compiled this type of data, even though such factors may strongly influence students' risk of injury. One non-school-related study in New York City showed that children living in low-income neighborhoods were twice as likely to suffer injuries as children in neighborhoods with few low-income households (24). It follows that students from low-income households are more likely to attend schools in low-income neighborhoods and to confront a broader range of risks in the school and non-school environment than students from more advantaged backgrounds (52). Conditions resulting from inadequate resources due to budgetary constraints, such as poor maintenance of school buildings (78), grounds, and equipment, or higher student-to-faculty ratios resulting in less supervision, are likely to have a significant impact on the potential for injury (52).

Boyce et al. surveyed school principals and nurses with regard to ecological variables that can affect the incidence of injuries at schools.[13] The results indicated that four particular variables were "significantly and independently predictive" of higher injury rate at a particular school: 1) increased length of school day; 2) presence of alternative educational programs; 3) less experienced school nurses; and 4) higher student-to-staff ratio. Significantly, two ecological factors were equally predictive with regard to severity of injury: greater length of school day and higher percentage of minority group students (10). More studies of the association between these factors and school injury rates are essential for understanding the ecological factors that impact the incidence of injury. The connections allow prevention efforts to appropriately target injury problems.

Severity

While overall incidence of school injury is tremendously important in determining the existence of an injury problem, equally important is

[13] The ecologic variables included: demographic characteristics (student enrollment, percentage of minority students, and student-staff ratio), social characteristics (transience rate, absence rate, drug or alcohol problems, family stability in student population, and behavior problems), programmatic characteristics, category of school (elementary, junior high school, high school), alternative educational programs, level of PTA (Parent-Teacher Association) activity, and school hours, physical characteristics (age of school building and playground condition), and health program characteristics (variety of nursing experience, years of nursing experience, nursing education, nurse hours, presence of nurse's aide, presence of safety program) (10).

injury severity. Severe injuries that can result in long-term disability justify attention due to their economic and emotional costs and health implications. Severity, however, is subjective and various terms are used to connote the gravity of an injury, including *severe, serious, significant,* and *major*. The percentage of severe injuries—ranging from 18 to 39 percent across studies—varies because, among other things, severity is defined differently from study to study (see table 3-1). The diversity of definitions inhibits meaningful cross-comparisons. Since most studies do not have medical diagnoses, other indicators are used as indices of severity, including the type of injury, nature of injury, school days lost, and school days in the hospital. Also the number of serious injuries compared to minor injuries is somewhat distorted because student injury report forms are usually completed by the attending adult, whether a teacher, school nurse, coach, or administrator, rather than by medical personnel. The extent of the distortion is unknown.

While most studies define severity by the type of injury (i.e., a fracture), each study uses a different set of criteria to determine if the type of injury is severe (69). According to Sheps and Evans, using the nature or body area of an injury to serve as a proxy for severity is generally unsound because, while they are associated, no specific correlation exists (26). For example, while a head injury is classified as severe, the actual injury may only be a surface abrasion on the head. However, nature of the injury appeared to have a stronger association with severity than body area. Moreover, the inclusion of particular types of injuries can substantially affect total numbers. In one study, for example, severe sports injuries increased from 25 to 56 percent if sprains, strains, and dislocations were classified as severe (69). Nonetheless, the variation of rates for severe injuries was small (0.9 to 1.7 severe / 100) compared to that of overall injury rates (1.7 to 9.2/100) (69).

Regardless of the definition used, playground and sports athletic injuries account not only for the greatest number of injuries, but also for the majority of severe injuries at school (10,43,69). Boyce et al. found that playground and sports equipment related injuries were 1.6 times more likely to be severe when compared to all other causes of injury. National Safety Council (NSC) data, however, indicate that motor vehicle-related injuries occurring on the trip to or from school resulted in the most severe injuries, indicated by the highest average number of school days lost (2.6 days) per injury, followed by interscholastic sports (1.6 days).

Passmore and Gallagher reported that the Massachusetts SCIPP data indicate that school injuries result in slightly lower proportions of hospital admissions and fewer bed-night stays than injuries occurring outside the school environment (63). Some of the more serious injuries incurred in schools are profiled in the NPTR study (29). Of the 907 emergency room cases identified during the NPTR study period December 1987 to February 1993 as being school-related, there were five deaths and nine debilitating injuries that required extensive rehabilitation. The injury rate may be influenced by students with pre-existing conditions, as they contributed disproportionately to the number of injuries. Many of the most serious injuries also resulted from falls: three of the five deaths and four of the nine rehabilitation cases. The most severe injuries for all students were associated with the head and spinal cord. All five deaths resulted from injuries to the head.

Cause

Falls (either from the same surface or from elevation), organized sports or athletics, and unorganized play were the activities most frequently associated with injuries (35,67). Sports activities accounted for a relatively high rate of severe injuries across studies. Comparison of the causes among studies, however, is not feasible because each study categorizes cause differently (69). To compound the problem, many studies approach the characterization of each cause differently. For example, Boyce et al. defined cause as "self, other student intentional, other student accidental, playground or sports equipment, mechanical equipment, and athletics," whereas Sheps and

Evans included "fall, mechanical or object related, struck by or against another person, sports injury including drowning, and foreign body in eye." The Utah student report form gives cause as a contributing factor, which includes "common falls, fighting, collision, compression, contact with equipment, hit with thrown object, overexertion, and tripped/slipped." These significant methodological variances must be resolved before comparative data can be developed (69).

Locale

Not surprisingly, the most common locales for school injuries were playgrounds, gymnasiums, and athletic fields (10,27,56,73,99). Lenaway et al. found that injuries on the playground, for which data were collected only in elementary grades, occurred close to three times more frequently than those in the gymnasium. Sheps and Evans found that 29 percent of injuries were sustained on the playground. Comparatively, the Boyce study estimate of 65 percent playground injuries is high; however, it includes both playground and gymnasium.

Better supervision of elementary school children, especially on the playground, was a common study recommendation to reduce the risk for falls and other injuries (22,77). Sheps and Evans found an overall relative risk of 6.3 between uncontrolled and controlled areas of the school environment, suggesting that playground and sports activities in school require more attention and targeted prevention.

Injuries in school buildings, which include auditoriums, classrooms, corridors, stairways, and lab and shop facilities, represent a significant portion of all injuries. The NSC reported that they accounted for 24 percent of the injuries. The Utah Department of Health data indicated that students in grades 7-12 sustained 9.7 percent of their injuries in lab activities and 5.4 percent in classroom activities. There is a marked lack of detailed information on exactly which classroom activities caused the injuries. For example, it is not known whether these injuries are occurring in specific types of classes, such as industrial arts, science, or home economics. Moreover, there has been no evaluation of whether certain locations are more frequently reported than others (e.g., sports injuries versus classroom injuries).

Type and Body Area

As found by Boyce et al., the majority of injury types were those normally associated with playgrounds and athletics: swelling, bumps, cuts, bruises, and sprains or strains (see table 3-2). Elementary students sustained more minor injuries (e.g., contusions, abrasions, and swelling), which accounted for the difference in rates between elementary and high school students (27,69) and the decreasing rate of injury in secondary school (27). Types of injuries and body areas affected by injuries were distinct between elementary and secondary students. Elementary

TABLE 3-2: Types of Injuries Among Students

Type of injury	No. (and percent) of injuries to students
Swelling or bump	1,439 (27.1)
Cut	917 (17.3)
Bruise	740 (14.0)
Sprain	588 (11.1)
Scrape/scratch	382 (7.2)
Fracture	298 (5.6)
Chipped or broken teeth	180 (3.4)
Torn cartilage/ligament	83 (1.6)
Dislocation	65 (1.2)
Nosebleed	60 (0.1)
Loss of consciousness	22 (0.4)
Internal injury	13 (0.2)
Other	515 (9.7)

*The numbers and percentages were calculated from the 5,302 reported injuries among the Canadian schoolchildren attending the schools included in the Feldman study. The type of injury was not specified in 32 instances.

SOURCE: W. Feldman et al., "Prospective Study of School Injuries: Incidence, Types, Related Factors and Initial Management," *Canadian Medical Journal* 129:1279–83, 1983.

school students injured the head and face most frequently, while secondary school students were more likely to injure the upper extremities (69). Secondary students suffered twice as many sprains, strains, and dislocations as elementary students; however, the rates of fracture, concussion, whiplash, and foreign body in the eye were comparable (69). As expected, the predominant injuries correlate with types sustained on playgrounds and athletic fields. With few exceptions, studies failed to analyze injuries sustained in classrooms. One study showed that classroom injuries most frequently consisted of cuts and abrasions, punctures, foreign bodies, and poison or burns (43).

Fractures were the most frequent of the more severe injuries. Feldman et al. reported that fractures accounted for 5.6 percent of overall injuries and occurred primarily in the hand (34.2 percent), wrist (18.8 percent), and arm (12.4 percent). Boyce et al. found that 13 percent of all injuries were fractures. In Utah, fractures represented the highest percentage of injuries for grades K-6 (26.4 percent) and the second highest for grades 7-12 (20.9 percent) (99).

Time, Day, and Month

Studies that have attempted to associate the time, day, or month of injury with injury incidence indicate that no one day had significantly more injuries than any other (27,43,73). However, injuries did peak at certain times during the day. Both the Feldman and Lenaway studies reported increased numbers of injuries during recess and lunch hour; similarly, the Utah data revealed an overwhelming majority (62.5 percent) of injuries among students in grades K-6 occurring during recess or lunch. This is not surprising given the Sheps and Evans finding that there were six times as many injuries in uncontrolled areas as compared to controlled areas of the school environment.

Distribution trends of injuries by month were also evident. Rates increased with the return to school and the advent of warm weather that allows more time outdoors. The highest frequency of cases was in September, followed by October. The fall injury rates may be attributable to the excitement of returning to school and to football, the leading cause of sports injuries, which is played during the fall months. Rates rose again in January, as students return to school after the holiday vacation. Of course, to the extent that the pattern varies according to climate, injury rates may rise and fall at different times of the year in different regions of the country (43).

Product and Equipment Involvement

The U.S. Consumer Products Safety Commission (CPSC) maintains the National Electronic Injury Surveillance System (NEISS), which collects injury data from a national sample of hospital emergency departments (see box 3-1). NEISS data is based on injuries that patients say are product-related only; therefore, the injuries are not necessarily caused by the product but only related to the product. Non-product-related injuries are not included. Although collected using school as a location, the data are not analyzed by that criterion. At the request of OTA, the CPSC produced raw data of injuries incurred at school by persons aged 5 to 18. CPSC did not analyze the data; the discussion below presents OTA's limited examination of the data by age, gender, body part injured, and severity. If the CPSC regularly analyzed these data, national estimates of school injuries, albeit only product-related injuries, could be provided. The NEISS data also includes medical diagnoses that provide more accurate information on the types of injuries occurring in schools than reports filed primarily by school staff.

Estimates from the 1993 NEISS data disclose that persons aged 5 to 18 incurred 670,584 injuries requiring treatment in a hospital emergency department. The younger children sustained the fewest injuries, but as the children got older they gradually incurred more injuries, peaking at age 14 or 15 and then gradually decreasing. Thirteen to 17-year-olds combined sustained about 56 percent of the injuries—14- and 15-year-olds alone accounted for nearly a quarter of all injuries.

Finger and ankle injuries were the most prevalent, 113,357 and 90,977 injuries, respectively. For 5- to 9-year-olds, head injuries were the most frequent, followed closely by finger and wrist injuries. Among 10- to 14-year-olds, finger injuries were the most prevalent; ankle and wrist injuries followed at about half the number of finger injuries each. Face, head, and knee injuries were each less than a third of finger injuries. For 15- to 18-year-olds, ankle injuries were the most frequent. Finger and knee injuries were also prominent injuries for this age group.

Ranking severity levels from 1 to 8 (8 meaning fatal), the most frequent severity level for 5- to 9-year-olds was level 3, accounting for almost a third of total injuries (31.7 percent). Severity levels 2 and 4 accounted for another 41 percent. There were zero injuries occurring in this study for severity levels 7 and 8, and only 0.9 percent of 5- to 9- year-olds had injuries of severity 6. For 10- to 14-year-olds, the most frequent severity level was level 1, accounting for 32.5 percent of the total injuries. Levels 2 and 3 accounted for more than half of the total number of injuries. The most frequent severity level for 15- to 18-year-olds was likewise level 1, accounting for 32.9 percent of the total injuries. Levels 2 and 3 accounted for a little less than half of the injuries incurred. While there were no injuries in 7 and 8 for students below age 15, for ages 15 to 18, 0.01 percent and 0.02 percent of the injuries were severity level 7 and 8, respectively.

The CPSC also produces safety alerts concerning consumer products; these include products used in schools. Two 1988 CPSC Safety Alerts involving mobile folding tables and audiovisual carts illustrate equipment hazards in schools. Mobile tables in school cafeterias are commonly 6 feet high when folded and weigh up to 350 pounds. When moved in the folded position, they can tip over and seriously injure a student. CPSC received reports of four deaths and 14 injuries to students who were moving such tables in the period 1980-1988, but the injuries generally occurred during after-school or non-school-sponsored events. Tip-over injuries also occurred with audiovisual carts in classrooms: in 1988, CPSC reported four deaths and nine serious injuries of students aged 7 to 11. All incidents involved slant-top carts, but CPSC noted concern over flat-top carts as well. Like folding tables, the carts characteristically overturned and injured the child pulling rather than the child pushing them.

The Massachusetts SCIPP data considered product involvement and concluded that 35.7 percent of school-related injuries involved products, 58.1 percent of which were structures (e.g., stairs, floors, walls, and fences) and sports or recreation equipment. Table 3-3 lists the types of injury-causing products that present risks to students in schools. Approximately 50 percent of the product-related injuries at school were sustained by 7- to 13-year-olds. Moreover, playground equipment is associated with about one-half of the injuries to 6- to 10-year-olds that involve sports or recreation equipment.

PLAYGROUND-RELATED INJURY DATA

Play is an integral part of each student's school day; it is a natural part of physical and cognitive development. School playgrounds provide elementary and junior high school students with the opportunity to develop motor, cognitive, perceptual, and social skills. The risk-taking part of that activity is inherent in the learning process. In the course of playing, however, children sustain injuries. Indeed, playground injuries are the leading cause of injuries to elementary and junior high students, ages 5 to 14, in the school environment. Relative to other school injury issues, playground safety has attracted much public attention and been the subject of considerable study. Researchers have collected and analyzed data on the nature, distribution, and prevention of injuries sustained on public playgrounds, providing insight into the ability to control such incidents at schools.

Sources and Limitations of Playground Injury Data

Because of the lack of national estimates of school injuries, there are no data available for

TABLE 3-3: Types of Products[a] Involved with Injuries in School

Products	Percent of school injuries involving products[b]
Structures and construction materials (e.g., stairs, floors, walls, fences)	29.2
Sports and recreation equipment	28.9
Furnishings, fixtures, and accessories	15.0
Powered and unpowered tools and workshop equipment (e.g., saws, drills, welding equipment, batteries, hoists)	7.1
Personal use items (e.g., clothing, pencils, pens)	6.1
Housewares (e.g., small kitchen appliances, drinking glasses, tableware, cutlery, cookware)	5.2
Food, alcohol, and medicine	1.9
Packaging and containers (e.g., cans, containers, glass bottles)	1.8
Heating, cooling, and ventilating equipment (e.g., radiators, fans, heating devices)	1.5
Communications, entertainment, and hobby equipment	0.5
Appliances	0.3
Miscellaneous	2.6

[a]These are the products involved with injuries at school to 1,704 children 5 to 19 years old in 14 Massachusetts communities, September 1979–August 1982. Products classified according to codes shown in United States Consumer Product Safety Commission (1987) and aggregated to general reporting levels commonly employed by the Commission (see, e.g., United States Consumer Product Safety Commission). Products are associated with an injury, but are not necessarily the cause of the injury.

[b]Products are involved with 35.7 percent of all school injuries.

SOURCE: From Harvard Injury Prevention Research Center analysis of injuries from SCIPP Injury Surveillance System data.

comparing playground injuries to other school injuries on a national level. It is clear, however, from the state surveys and epidemiological studies focusing on school injuries, that playground injuries are the primary cause of injuries in the school environment for younger students. Definitional issues provided the greatest obstacle for assessing the extent of such injuries. Depending on the study, a playground injury could include minor injuries as well as injuries necessitating a visit to a doctor or to an emergency room. Moreover, some studies of playground injuries have included all injuries sustained on playgrounds, whereas other data, such as the CPSC's NEISS data, may only record injuries involving playground equipment.

OTA reviewed the following data sources: 1) CPSC NEISS data; 2) state survey and study data; 3) epidemiological studies; and 4) the 1994 U.S. Public Interest Research Group (PIRG) and Consumer Federation of America (CFA) *Playing It Safe* survey. Each source, as discussed in box 3-3, has substantial limitations for purposes of this report. In addition, the sources have varying sample populations and distinct methods that do not allow cross-comparisons of conclusions.

Incidence and Distribution of Playground Injuries

Mortality Data (Equipment-Related)

The 1990 CPSC *Playground Equipment-Related Injuries and Deaths* report (the CPSC Report) provides an analysis of data on playground injuries and deaths associated with playground equipment. In the 16-year study period, 276 deaths of children were identified as playground equipment-related, for an average of 17 deaths each year. **Fatalities among school-aged children averaged nine per year**: approximately 50 percent to children under age 6, about 75 percent to children under age 9, and 90 percent to children under age 12. The CPSC Report did not distinguish whether these occurred on public, home, or homemade equipment. OTA could not identify national estimates of the number of total playground non-equipment-related fatalities.

BOX 3-3: Sources of Data on Playground Injuries in School

National data

The only national data for playground injuries are derived from CPSC's National Electronic Injury Surveillance System (NEISS) database, which keeps statistics on playground equipment-related deaths and injuries that are recorded in hospital emergency rooms. NEISS records only fatalities that are product-related injuries and, accordingly, excludes those that occur on playgrounds but are not equipment-related. Moreover, NEISS collects only emergency room data, providing only information on the more serious playground equipment-related injuries. NEISS reports on playground equipment that is public, used at home, or homemade.

In April 1990, CPSC published a report entitled Playground Equipment-Related Injuries and Deaths. For the report, CPSC examined 1973–89 NEISS fatality data, CPSC files containing death certificate information, consumer complaints, newspaper clippings, and other sources to obtain fatality data. Nonfatal injury data were obtained from a special study of NEISS data that analyzed information from April to December 1988 (which was extrapolated to a full year). For both mortality and morbidity estimates, the data were limited to children under age 15.

From analyses of playground injury data, CPSC published playground equipment safety guidelines in 1991. The guidelines are intended for those who purchase, install, maintain, and use playground equipment; however, they are not mandatory (see box 3-4). In addition, more technical standards that are voluntarily applicable to manufacturers have been devised by the American Society for Tests and Materials (ASTM).

State data

OTA identified six states that have some data on school playground injuries. These are the best sources of data for school playground injuries because injuries are reported in relation to other school-related injuries and include minor as well as serious injuries. Moreover, the data are not limited to injuries associated with playground equipment but include all injuries sustained on school playgrounds. Hawaii, South Carolina, Utah, and Washington include playground injuries in their surveys and studies of the entire range of school injuries, as reviewed in the previous section (see box 3–2). The data has been used by these states to develop safety programs. The Utah school injury data was used to design a curriculum guide for promoting playground safely in schools. Furthermore, the Utah data were also used for a 1993 study by the Centers for Disease Control and Prevention (CDC) of injury rates from falls for grades K–6 students on Utah playgrounds. The analysis was restricted to injury report forms detailing a fall involving equipment on the playground or athletic field. Arizona and Virginia have completed studies that focus specifically on school playground injuries.

The **Arizona Department of Health Services** completed a comprehensive school playground injury study from 1991 to 1992. However, the study included athletics and sports, so estimates are not restricted purely to playground-related injuries. It evaluated 212 elementary schools including 122,056 students in grades K–8, representing 29 percent of that population. Student health personnel were required to complete a report form when an injured student either 1) was sent home, 2) was sent to a physician, 3) was transported or admitted to a hospital, or 4) required restricted activity. The study was intended to reduce the number of injuries by providing the opportunity to target appropriate interventions.

In 1991, the **Virginia Department of Education** conducted a study on the safety of school playgrounds in that state. However, significant methodological problems with both the survey and the responses limit the reliability of those data. As part of the study, the Department of Education surveyed 75 school districts, of which 65 responded. The districts, representing 348,976 students enrolled in schools that had playgrounds, reported the numbers and types of injuries sustained on school playgrounds; there was no information relating to the grade,. age, or sex of the students. One of the major problems of the study was the inconsistent reporting. For example, school districts reported 5,708 total injuries but 12,734 injuries when classified by type, resulting in a more than twofold disparity in the number of injuries.

(continued)

BOX 3-3: Sources of Data on Playground Injuries in School (Cont'd.)

Epidemiological studies

State school injury data and epidemiological studies of the percentages of school playground injuries in relation to other school injuries are remarkably consistent. The epidemiological studies discussed earlier provide valuable insight into the incidence of playground injuries, because many of the epidemiological studies, as discussed in box 3-1, cover the complete school injury experience, allowing playground injuries to be studied relative to other school injuries. The epidemiological study conducted in Tucson, Arizona, by Boyce et al. (1984) evaluated playground injury data separately from other school injuries. There are also a number of studies that concentrate on playground injuries alone, in particular Sosin's study of the surface-specific injury rates on Utah school playgrounds and Bond and Peck's study of injuries on Boston playgrounds.

SOURCES: Office of Technology Assessment, 1995. Bond, M.T., and Peck, M.G., "The Risk of Childhood Injury on Boston's Playground Equipment and Surfaces," *American Journal of Public Health* 83:731–733, 1993. Sosin, D.M., et al., "Surface-Specific Fall Injury Rates on Utah School Playgrounds," *American Journal of Public Health* 83:773–735, 1993.

Strangulation resulting from entanglement and entrapment was the primary cause of fatalities; it was responsible for about 47 percent of the deaths. However, these deaths typically involved children under the age of 5, not school-aged children. Falls were the second highest cause of death (31 percent). The authors noted, however, that the number of falls is probably underreported, since in 1983 the CPSC ceased collecting death certificate information involving accidental falls except for one or two states (75). For fall-related deaths, the associated equipment included swings (52 percent), slides (24 percent), and climbers (17 percent). Equipment tipover or failures were associated with 13.5 percent of the deaths.

Morbidity Data

For each death on playgrounds there were approximately 14,000 emergency room visits for treatment of playground equipment-related injuries. In 1992, public playground equipment injuries were responsible for approximately 241,180 visits to emergency rooms.[14] The American Academy of Orthopedic Surgeons estimated the total cost of playground equipment-related injuries to children under age 15 at $1 billion in 1992.[15] There are no national estimates encompassing the complete extent of school playground injuries since the CPSC estimate is limited to equipment-related injuries and does not include injuries treated at schools, homes, and doctors' offices; however, it provides estimates of injuries by location, age, and time.

For each death on playgrounds there were approximately 10,000 emergency room visits for treatment of playground equipment-related injuries. CPSC projected about 200,000 playground equipment-related injuries in 1988; however, when adjusted by the proportions of verified cases for the CPSC Report, the number was reduced to about 170,000 (75).[16] Public equipment was involved in 70 percent of these injuries; home equipment and homemade equipment accounted for 24 and 4 percent, respectively. Most of the public equipment injury incidents occurred in school playgrounds and public parks,

[14] "Public playground equipment" refers to "equipment intended for the use in the play areas of parks, schools, childcare facilities, institutions, multiple family dwellings, restaurants, resorts and recreational developments and other areas of public use" (83).

[15] Costs include, but are not limited to, medical and travel expenses for initial and follow-up treatment, forgone earnings of the injured child's visitors, and disability costs.

[16] From April to December 1988, CPSC completed an in-depth special study of selected playground injury incidents. The study identified cases involving injuries that were not associated with outdoor playground equipment. Extrapolating the percentage of these cases to the 1988 NEISS, CPSC determined that the estimated 201,400 emergency room-treated playground equipment-related injuries should be reduced to 170,200. The special study was limited to 1988 data.

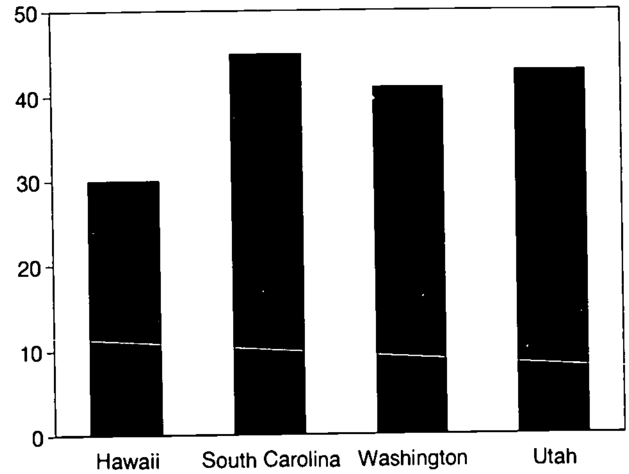
each accounting for approximately 42 percent of the 1988 estimated injuries incurred on public playgrounds. Using this data, OTA calculated that approximately 30 percent of publicly owned playground equipment injuries occurred on school playgrounds. Furthermore, 13,000 playground equipment-related injuries to school-aged children occurred on school playgrounds during school hours, which is about 8 percent of playground equipment-related injuries.

The CPSC's most current estimate of 241,181 playground equipment injuries requiring treatment in hospital emergency rooms in 1992 has not been adjusted in the manner of the 1988 data. The estimate includes 168,827 public playground equipment, 57,883 home playground equipment, and 14,471 homemade playground equipment injuries (84).

Playground injuries were the most prevalent of all injuries sustained by students in school, accounting for 30 to 45 percent of all school-related injuries reported in the available state data (see figure 3-2). This is also true of the epidemiological studies; the percentages of playground injuries ranged from 29 to 43 percent of total school injuries. The percentages are even higher when limited to children in grades K-6. For example, Utah reported that playground injuries accounted for about 65 percent of all school injuries for those grades. Besides being the most prevalent, playground injuries represented some of the most severe injuries (11,27). Boyce et al. found that a quarter of the playground injuries were severe, meaning that they resulted in concussions, crush wounds, fractures, and multiple injuries.

Unlike school injuries in general, there was no significant difference between the frequency of injuries suffered by boys and girls (11,71,75). For all children, the body area most frequently affected by playground equipment-related injuries was the head and face (47 percent), followed by the arm and hand (34 percent). Children under the age of 6 were significantly more likely to sustain an injury that involved the head or face (60 percent) than the arm or hand (20 percent). Injuries were more equally distributed across body areas for children ages 6 and over (75).

FIGURE 3-2: Percentage of Playground Injuries in Four State Studies



SOURCE: Office of Technology Assessment, 1995, based on Hawaii Department of Education, "Summary-School Accident Report, 1989–1990" (Honolulu, HI: 1991); Washington State Department of Health, Office of Community Environmental Health Programs, *The School Injury Surveillance Project" Results and Recommendations* (Olympia, WA: 1990); South Carolina Department of Health & Environmental Control, Division of Children's Health, *Annual School Nurse Survey 1993* (Columbia, SC: 1994); and Utah Department of Health, Division of Family Health Services, Student Injury Report Database, 1988–1992.

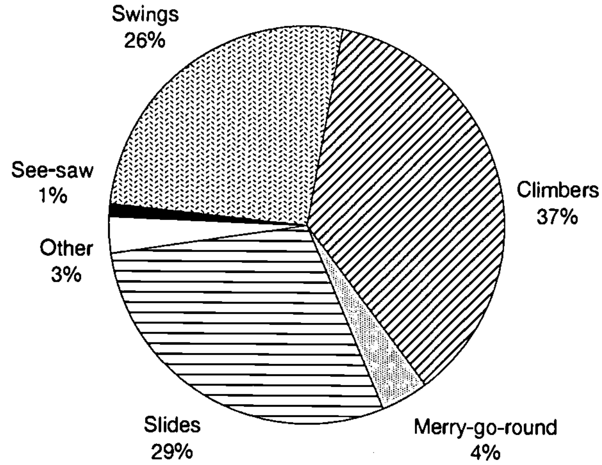
The types of injuries most frequently sustained on playgrounds were abrasions, contusions, sprains, dislocations, lacerations, and fractures (3,75). The percentages reported by CPSC were as follows: 29 percent lacerations, 28 percent fractures, 22 percent contusion/abrasions, and 13 percent strain/sprains. Lacerations, contusions, and abrasions—relatively minor injuries—were associated with 81 percent of the head injuries; however, 7 percent of the head injuries were potentially more serious, involving fractures, concussions, and internal injuries. Fractures were the most frequent arm and hand injuries, accounting for 65 percent. Strains and sprains accounted for another 22 percent of the arm and hand injuries (75).

The Arizona Department of Health playground study found that 72 percent of the students with reportable injuries were taken to a doctor or the emergency room: 38 percent were taken to the doctor by parents, about 19 percent were taken to the emergency room by parents, and about 15 percent were taken to the doctor or emergency room by school personnel. Of these students, 1 percent were hospitalized with a mean stay of 1.9 days (the longest was 7 days). Moreover, 15 percent of the students taken to a doctor or emergency room required restricted activity for an average of 13.6 days (the longest being 120 days). The study estimated that in Arizona the 10,500 school playground injuries resulted in 6,500 days of absenteeism, 4,300 doctor visits, and 2,000 emergency room visits.

Many of the studies focused on the association between playground equipment and injuries. Boyce et al. found that about 23 percent of the total injuries across all grades in public schools were associated with playground equipment; the rate of playground equipment-related injury at the schools was about 0.9 playground equipment injury per 100 student years (11).[17] Lenaway et al. found that playground-related equipment injuries alone accounted for 38 percent of all school injuries, the rate of injury being about 2.4 per 100 students (43). The equipment most often involved in injury-causing events were climbers, swings, and slides (see figure 3-3). Among 5- to 14-year-olds, climbers and swings accounted for 71 percent of injuries (75). Other equipment commonly involved in playground injuries included slides (15.5 percent) and teeter-totters and seesaws (3.4 percent) (75). Across studies, remarkably similar percentages were reported (3,9,43).

As shown in figure 3-4, falls associated with playground equipment present the greatest risk to students. Falls from climbing equipment accounted for nearly 25 percent of the injuries on public playgrounds (75) and a disproportionate number of severe injuries (11). The body areas most affected by falls to the surface were arm and hand (47 percent) and head or face (36 percent). The overwhelming majority of serious arm and hand injuries resulted in fractures (70 percent).[18] Falls to the surface involved mainly climbers, swings, and slides. In fact, falls to the surface from climbers accounted for 23 percent of all the playground equipment-related injuries; surface falls from swings and slides accounted for approximately 16 and 13 percent, respectively.

FIGURE 3-3: Injuries Associated with Public Playground Equipment, by Type of Equipment (N=10,730)



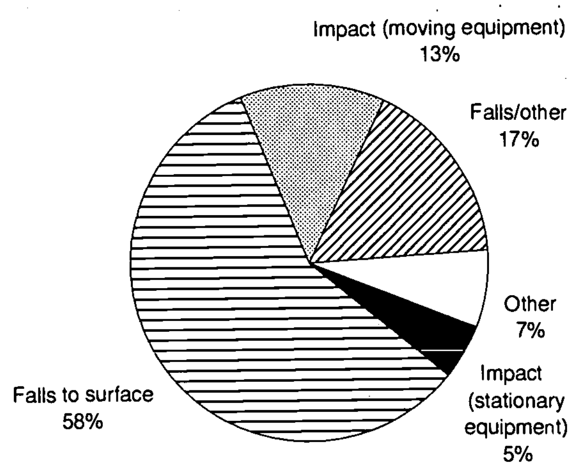
SOURCE: National Electronic Injury Surveillance System (NEISS) Special Study, Apr.–Dec. 1988. U.S. Consumer Product Safety Commission/EPHA.

Although climbers, slides, and swings accounted for about 87 percent of the overall playground injuries, CPSC found that the proportion of injuries attributed to each type of playground equipment was nearly equivalent to the proportion of each type of equipment used, suggesting that no one type was particularly more risky than any other (75). While no analysis was

[17] The study also found that higher incident rates correlated with two ecologic variables, small student enrollment and the presence of alternative education programs (e.g., magnet schools). Alternative schools had a mean injury rate of 1.37 per 100 student years compared to 0.71 in other elementary schools (10).

[18] Serious head injuries due to falls from heights of more than 4.5 feet were reported. There did not appear to be a strong correlation between diagnosis and the distance of the fall; however, some fractures, to the wrist and collarbone, occurred at falls from heights of two feet or less (75).

FIGURE 3-4: Incidents Involving Playground Equipment



SOURCE: National Electronic Injury Surveillance System (NEISS) Special Study, Apr.–Dec. 1988. U.S. Consumer Product Safety Commission/EPHA.

completed relating the state of the equipment to the injury rate, three-quarters of the equipment involved in injuries was reported in good condition and only one-tenth of the equipment was reported to be abused, scarred, rusted, or broken. The study, however, did not consider whether there was good protective surfacing, or whether the playground equipment was adequately spaced or at a safe height.

The available studies on the adequacy of surfacing on public playgrounds have, without exception, found that most playground surfacing is unsafe. A study of Boston playgrounds conducted by the Childhood Injury Prevention Program of the Boston Department of Health and Hospitals found that all the surfaces observed were unsafe (9). Sixty-four percent of the surfacing was appropriate (matting, sand, or wood chips) but poorly maintained—making it unsafe. The remaining 36 percent was unsafe due to unsuitable playground surfacing material (asphalt, grass, bare ground). Similarly, a survey of 57 elementary schools around Philadelphia revealed that 99 percent of climbers and slides, equipment associated with many injuries, were placed on inappropriate surfacing of asphalt or packed dirt (65). A 1994 study performed by the PIRG and CFA, *Playing It Safe,* presented the findings from observation of 443 playgrounds in 22 states (102). Consistent with the above findings, 92 percent of the playgrounds lacked "adequate protective surfacing," meaning loose fill material (e.g., hardwood chips) properly maintained at depths of 9 to 12 inches under or around all equipment.[19] Thirteen percent had hard surfaces under and around all equipment, a substantial decrease from the 31 percent found in 1992.

For playground injuries, the problem is not so much lack of data, but rather the lack of the necessary implementation of the safety recommendations and rigorous maintenance of playground equipment. Based on CPSC and other epidemiological studies, voluntary guidelines for safe playgrounds have been devised, and intervention and prevention strategies have been developed (see box 3-4). Short of developing mandatory playground standards, those responsible for the construction and maintenance of playgrounds should be included in efforts to make playgrounds safe and to minimize injuries. Box 3-5 illustrates the impact a successful playground safety program can have on preventing injuries. Physical playground site safety should also be combined with staff supervision of the students. Programs designed to increase supervision have resulted in reductions of injuries (77).

SCHOOL ATHLETIC INJURY DATA

By participating in physical education and interscholastic sports, students benefit from the advantages of regular exercise (33), the opportunity to develop motor and judgment skills, and participation in competitive team sports. Engaging in sports activities entails some risk of being

[19] Of the 443 playgrounds observed for the PIRG and CFA *Playing It Safe* report, 62 percent had loose fill surfacing but only 3 percent maintained the loose fill at an adequate depth of at least 9 inches. In addition, 19 percent had loose-filled surfacing under some equipment, but hard surfaces under other equipment. Only 5 percent of the playgrounds had synthetic surfacing, such as premolded rubber tiles, under and around all equipment.

BOX 3-4: Playground Guidelines and Standards

Public playgrounds cannot exist without injuries. Due to the nature of the playground equipment, potential hazards exist, even when safety standards are met and maintained. The U.S. Consumer Product Safety Commission (CPSC) and the American Society for Testing and Materials (ASTM) have published safety standards for playground equipment to minimize the risk of injuries.

The guidelines recommended by the CPSC are based on a March 1990 report by the COMSIS Corporation. The CPSC handbook, which evaluates the safety of each individual piece of playground equipment along with the entire layout of the playground, is intended for school officials, parents, equipment purchasers, recreation personnel, and anyone else concerned with general playground safety.

ASTM guidelines provide a more technical approach than CPSC standards. Guidelines recommended by the ASTM, published in December 1993, are directed toward equipment manufacturers, designers, and playground planners rather than toward the general public. ASTM standards focus on technical details, including testing information, and are stricter and more extensive than the CPSC standards.

However, these guidelines and standards, which include design, layout, installation, construction, and maintenance, are not mandatory. Schools, child centers, parks, and other public facilities must voluntarily upgrade and maintain the equipment and surrounding areas to help prevent injuries and deaths resulting from incidents related to playground equipment.

Many of the injuries and deaths related to playground equipment can be prevented by providing safer playground equipment. By limiting the height of equipment and providing adequate fall zones and protective surfaces, many injuries and deaths caused by falls would not occur or would be less severe. These injuries could also be prevented by providing adequate protective surfacing. Of 443 playgrounds investigated by the Public Interest Research Group (PIRG) and CFA using CPSC standards, 92 percent did not maintain adequate protective surfacing under and around equipment. Since 1992, fewer playgrounds surveyed had hard surfaces (from 31 percent in 1992 to 13 percent in 1994), such as asphalt and concrete, below the equipment.

According to the guidelines, protective materials should be soft so as to reduce the severity of injuries due to falls. Hard surfaces, such as asphalt, concrete, grass, and packed dirt, do not provide enough protection. Loose-fill materials like sand and hard wood chips, along with unitary synthetic surfaces such as molded rubber tiles, are acceptable when maintained properly. Maintenance of the materials requires keeping proper depths (compressed or uncompressed). Depending on the type of equipment and distance a child might fall, different materials gave different critical heights. For example, compressed double shredded bark mulch at a depth of 9 inches had a critical height of 7 feet, while uncompressed double shredded bark mulch's tested critical height was 10 feet. A difference in critical heights is also seen when comparing wood mulch (10 feet) to fine sand (5 feet) at uncompressed depths of 9 inches.

Adequate fall zones may be often missing. Often protective surfaces did not extend far enough around the equipment, or other structures are built too close. Again, depending on the type of equipment, varying fall zones are recommended. For instance, for a single-axis swing set, CPSC recommends a distance of 6 feet from the perimeter of the supports and a distance that is twice the greatest possible height, both in front of and behind the swings, as a safe fall zone that should have protective surfaces.

Another problem is that in building the structures recommended, height limitations are not always adhered to. Instead, some structures, such as climbers and slides, are built so that if a child falls from them, there is a greater potential for injury than if it was a smaller structure that was equally challenging yet less dangerous. Height limitations depend on the type of equipment, and also on the age of the children using it. For instance, older students have more muscle control and better natural instincts (e.g., to risk an arm to protect the head) than younger children. Therefore, the structures intended for older student use could be built at greater height without a proportionate increase in danger.

SOURCES: U.S. Consumer Product Safety Commission, Handbook for Public Playground Safety, 1991; U.S. Public Interest Research Group and Consumer Federation of America, *Playing it Safe: A Second Nationwide Safety Survey of Public Playgrounds*, May 1994.

BOX 3-5: An Effective Injury Prevention Program

After seeing many children come into the trauma unit with injuries incurred on the playgrounds or indirectly caused by the lack of playgrounds, Barbara Barlow, MD, director of pediatric surgery at the Harlem Hospital Center in New York City, decided to start an injury prevention program. Founded in 1988 and based at the Harlem Hospital Center, the Injury Prevention Program (IPP) has three main targets: playground injury prevention, motor vehicle/pedestrian/bicycle injury prevention, and window guards to prevent falls. Other projects have also grown out of the IPP, such as art and dance programs to keep children off the streets and away from drugs and gunfire.

Working with public schools, state and community agencies, and volunteers from the community, the IPP has contributed to the reduction of the number of children patients at the Harlem Hospital Center. From 1988 to 1993, a reported 38 percent decrease in major trauma and 42 percent decrease in major injury admissions involving children of Central Harlem has occurred (IPP, 1994). Project Oasis and Safety City are two exemplary programs of the IPP that have aided in the dramatic decrease in childhood injuries. These programs implement key parts of the IPP mission: upgrading playgrounds at school, introducing safety features, and teaching the children how to safely encounter traffic situations, such as crossing the street.

Project Oasis focuses on improving the safety of school playgrounds and creating gardens for the schoolchildren. Before the involvement of IPP, school playgrounds often consisted of concrete slabs and rusty monkey bars. While school officials recognized the need to upgrade the playgrounds, monetary and labor resources were not readily available. With the efforts of IPP, the resources were found in grants and contributions of both money and labor. Safety improvements included rubber matting below swings, slides, and jungle gyms; rounded corners on the wooden structures; and railings on elevated structures. These features, among others, have considerably reduced the occurrence of preventable playground injuries, and consequently have reduced the risks of the children at the schools that have reconstructed playgrounds. Since 1988, IPP has completed the reconstruction of four playgrounds and has plans for four more playgrounds at Harlem schools (IPP, 1994).

In addition to rebuilding playgrounds, the IPP has joined forces with the New York City Department of Transportation and the New York public schools to establish **Safety City,** a program that educates students about traffic safety. With few suitable playgrounds available, children often turn to the streets as a place to play; as a result, motor vehicle crashes have been a leading cause of death and injury to New York City children. Safety City teaches third-grade students in the community street safety skills in a full-size yet protected street section built on the school grounds. The children are able to learn street safety in the fenced-in area, which includes real trucks and cars, street signs and signals, and other street paraphernalia. The realistic approach to learning has dramatically reduced the number of preventable deaths and injuries due to traffic accidents involving children. Since the onset of the program, hospital admissions for accidents involving motor vehicles and pedestrians have dropped by 5 percent (IPP, 1994). The IPP has prevented numerous injuries and deaths by successfully teaching the children of Harlem the importance of street safety.

SOURCES: T. Hiss and E. Koren, "Child's Play: New York's Best Places to Play," *The New Yorker* 69(14):80, May 24, 1993; Injury Prevention Program, "Injury Prevention Using Community Coalitions," unpublished article sent by IPP, New York, NY, 1994; R. Mora, "The Creative Playground/Outdoor Learning Center," *Children's Environments Quarterly* 8(1):59–62, 1991; New York City Department of Transportation, "Safety City," New York, NY, June 1992; "An Ounce of Prevention: ED's Outreach Efforts to Reduce Childhood Injuries," *ED Management*, April 1994, pp. 59–61; "Project Oasis: New Playground and Garden Thrive in Harlem," *Columbia Community Affairs*, January 1994, p. 15; A.A. Sgarro, "A Surgeon and Her Community," *Vassar Quarterly*, spring 1993, pp. 10–13; "The Unique Safety Street in Harlem," *Childhood Injury Prevention Quarterly*, fall 1992, p. 5.

injured as all such activities involve some degree of danger. In 1993, approximately 5.6 million students competed in high school athletics (51)—about 43 percent of high school students (85). Student participation in athletic activities is a principal cause of junior high and high school injuries and results in a significant number of debilitating injuries and deaths each school year.

Compared to the number of studies on sports injuries in general, few have been directed specifically at school athletic injuries. Most studies survey all sports injuries, including recreational, community, or school athletic activities. This lack of school specific data makes it difficult to draw conclusions regarding athletic-related injuries occurring only in the school environment. The majority of information focuses on junior high and high school student sports injuries primarily because these students are typically the segment of the school-aged population participating in athletics, and thus sustaining the majority of athletic injuries.

Sources and Limitations of Athletic Injury Data

The major sources of school athletic injury data, as shown in box 3-6, are the National Center for Catastrophic Sports Injury Research, CPSC's NEISS database, the National Athletic Trainers Association, and epidemiological studies. In addition, the American Academy of Pediatrics publication *Sports Medicine: Health Care for Young Athletes* reviews sports injury studies, although they are not limited to schools. Sources providing athletic injury data suffer from the same problems as organizations reporting injury data in general. Limitations of studies typically include: underreporting, inconsistent definitions of athletic injury, inaccurate reporting of injuries, unavailability of athletic exposure times, discrepant criteria for classifying severe or serious injury, and inability to control for certain variables (33).

School sports injuries, or risks, are expressed in a number of ways in different studies, including: 1) total number of injuries, 2) percentage of overall injuries that occur in school, 3) number of injuries per student population, 4) number of injuries per student population participating in a particular sport, 5) number of injuries per athletic season, and 6) number of injuries per duration of athletic exposure (days or hours). Risk is portrayed most accurately by the number of injuries per duration of athletic exposure because it adjusts for differences in the lengths of seasons (64). As typically used, athletic exposure means "one athlete participating in one practice or contest where he or she is exposed to the possibility of an athletic injury" (64). The other measures used and the different indices of severity (for example, missed academic days and missed practices or competition days) inhibit cross-comparison of studies.

Epidemiological studies are directed at determining the distribution or rate of health injuries that result from athletic participation. Most often, the studies focus on a particular problem associated with a single sport. Few studies have examined the range of athletic injuries in the school environment; physical education injury studies are particularly lacking. The major school sports injury studies include those of Garrick and Requa (31), Zariczny j et al. (104), and Rice (64) (see table 3-4). Both the Garrick and Requa and the Zaricznyj et al. studies are over a decade old, and each was a study in one city. In 1978, Garrick and Requa published their study of student athletes in four high schools in Seattle, Washington, over a two-year period, 1973-75 (31). In 1980, Zaricznyj et al. studied reports of injuries to all school-aged children and adolescents in Springfield, Illinois, from 1974 (104). The Zaricznyj study evaluated all types of injuries sustained during participation in physical education, school team sports, community team sports, and nonorganized sports.

Rice studied sports injuries in 20 high schools in the Seattle and Puget Sound areas of Washington state since 1979. He established a sports injury surveillance system and instructed coaches in record keeping and completing a Daily Injury Report (DIR) to record the participation status and types of injuries at practices

BOX 3-6: National and State Sources of Data on Sports Injuries in Schools

The National Center for Catastrophic Sports Injury (the Center) at the University of North Carolina records catastrophic injuries occurring in all high school and college sports for both men and women. Since 1982, researchers have recorded catastrophic injuries in high school sports nationally. The Center is funded by grants from the National Collegiate Athletic Association, the American Football Coaches Association, and the National Federation of State High School Associations. The Center was founded, in part, to counter the lack of sports injury data, particularly for women. Data are collected from coaches, athletic directors, executive officers of state and national athletic organizations, a national newspaper clipping service, and a team of researchers. When the Center is notified of a possible catastrophic injury, the injured player's coach or athletic director is contacted by telephone, personal letter, and questionnaire. The most current edition of the data reviews information collected from the fall of 1982 to the spring of 1992.

The Center defines catastrophic injury as any severe injury incurred during participation in a sport. Catastrophic includes three degrees of injury: fatal, nonfatal, and serious. Nonfatal injuries are those resulting in permanent severe functional disability, while serious injuries result in severe injury without permanent functional disability (i.e., a fractured cervical vertebra with no paralysis). The Center also categorizes injuries as direct or indirect—direct meaning those injuries that resulted directly from participation in the skills of the sport; indirect meaning those injuries that were caused by systemic failure as a result of exertion while participating in a sport activity or by a complication that was secondary to a nonfatal injury.

The CPSC's **NEISS** database (see box 3-3) contains national estimates of the number of nonfatal injuries incurred by school-aged sports participants; currently the data are not analyzed using school as a location for injury. However, these data can be broken down by age and location to give some sense of sports injuries at school. NEISS data, however, include only those injuries involving consumer products and come from a sample of patients in hospital emergency rooms. Many athletic injuries are never seen in hospital emergency rooms but are tended to by sports trainers or doctors. Moreover, hospital emergency room data inherently contain a selection bias since, except for the most serious injuries, the cost of emergency care affects the decision to seek medical care. CPSC also identifies sports-related deaths from NEISS data and other data sources (death certificates, newspaper clippings, consumer complaints, and medical examiner reports).

The **National Athletics Trainer's Association** (NATA) completed a single-year sports injury surveillance study. The 1986 study was based on medical records of 32,647 of the estimated two million high school athletes participating in football, basketball, and wrestling. NATA extrapolated from the injuries incurred in those three sports to include all other sports. The authors recognized that the study included only those schools that had certified athletic trainers or the equivalent on staff, which only includes 16 to 18 percent of all schools. The fact that these schools have that level care probably indicates that they are more likely to be sensitive to preventing athletic injuries.

In addition, the **Kansas Department of Health and Environment** completed a survey of athletic injuries in secondary schools during the 1990–91 academic year. The survey covered a random sample of 283 schools, with 162 responding. Injuries were reported for grades 7 to 12, but rates were calculated only for grades 9 to 12.

SOURCE: Office of Technology Assessment, 1995.

TABLE 3-4: School Athletic Injury Studies			
	Garrick and Requa (1978)	**Zaricznyj et al. (1980)**	**Rice (1992)**
Location	Seattle, WA	Springfield, IL	Seattle, WA (Puget Sound area)
Population studied	3,049 high school student sport participants	25,512 school-aged children	6,057 high school athletes
Method of assessment	An athletic trainer was assigned to each of the four high schools studied to collect case and control data on injuries to athletes.	For one year, reports were received from principals and coaches of all 53 public and private schools, supervisors of community sports programs, two hospital emergency rooms, schools' accident insurance company and local physicians.	Coach or student trainer, adult athletic trainer, or manager reported injuries on a "Daily Injury Report," which was completed daily and submitted monthly.
Reportable injury	A medical problem resulting from athletic participation necessitating removal from a practice or competitive event and/or resulting in missing practice or competitive event.	Any traumatic act against the body sufficiently serious to have required first aid, filing of school accident reports, or medical treatment.	A medical problem resulting from athletic participation necessitating removal (or limiting participation) from a practice or competitive event and/or missing a subsequent practice or competitive event. An injury implies a time loss—either missing a practice or game or participating on a limited basis.
Incidence of injury	39 injuries per 100 student participants	About half of all sports injuries sustained by school-aged children in the community occurred in physical education class (15 percent) and organized school sports (38 percent).	32.7 injuries/100 athletes/ season and 7.8 injuries/1,000 athletic exposures. Mean injury time loss (practices and games) was 4.6 days.
Severe/ serious	*Severe injury:* indexes of the severity of injuries sustained include time lost (from practice and /or events), the necessity for special diagnostic tests (e.g., x-ray films) or the need for physician consultation, hospitalization, or operative procedures.	*Serious injuries:* injuries causing disruption of one or more supporting structures of the body or damage to important organs (e.g., brain, liver, kidneys etc.). *Permanent injuries* are those in which body structure was not restorable to its original anatomy or function, such as a broken tooth.	Severity categorized by the amount of time lost from full unrestricted participation. Injuries that kept an athlete from participation are *minor*, those with time loss between one and three weeks are *significant* and those with time loss over three weeks are termed *major*.
Incidence of severe/ serious	About 75% of the injured students returned to practice with fewer than five days of practice or competition missed. 42% were examined by a physician (note: 53% of wrestling injuries were examined by a physician).	20% of the injuries were serious. About half of the serious injuries were related to schools sports, physical education (27%), and organized team sports (25%). Nonorganized sports accounted for about 48% of the serious injuries.	1.8 significant injuries/1,000 athletic exposures. 0.5 major injuries/1,000 athletic exposures.

(continued)

TABLE 3-4: School Athletic Injury Studies (Cont'd.)

Sports with highest injury rates	Highest rates were in: football (81/100) and wrestling (75/100). Overall sport injury rates were lower in the second year of study, primarily due to elimination of trampoline as a competitive event.	Highest injury to participant ratios in school team sports were football (28%), wrestling (16%), and gymnastics (13%).	ALL INJURIES *football:* 70.6 injuries/athlete season; 15.1 injuries/1,000 athletic exposures. *girls' cross-country:* 58.8 injuries/athlete season; 14.7 injuries/1,000 athletic exposures.
		Overall: football (19%), basketball (15%), gym games (11%), baseball (10%), and roller-skating (6%). *PE class*: of 594 injuries, basketball (142), gym activity (164), gymnastics (44), volley ball (45), and football (40). *School sports teams*: of 229 injuries, football (126), basketball (29), wrestling (27), and track and field (23).	*boys' cross-country:* 55.3 injuries/athletic season; 13.1 injuries/1,000 athletic exposures. *girls' soccer:* 41.4 injuries/athlete season; 10.2 injuries/1,000 athletic exposures. *wrestling:* 41.9 injuries/athlete season; 9.5 injuries/1,000 athletic exposures. SIGNIFICANT INJURY RATES *football:* 3.8 injuries/1,000 athletic exposures. *boys' cross-country:* 3.5 injuries/1,000 athletic exposures. *wrestling:* 3.2 injuries/1,000 athletic exposures. *girls' cross-country:* 2.9 injuries/1,000 athletic exposures. *girls' soccer:* 2.2 injuries/1,000 athletic exposures. MAJOR INJURY RATES *wrestling:* 1.2 injuries/1,000 athletic exposures. *football:* 1.1 injuries/1,000 athletic exposures. *girls' cross-country:* 1.0 injuries/1,000 athletic exposures.

SOURCE: Office of Technology Assessment, 1995.

and contests. The participation status indicated whether each athlete was present at full participation, present but participating on a limited basis only, unable to participate due to injury, or not at practice (absent or sick).

Incidence and Distribution of Athletic Injuries

Mortality Data

The only national school sports injury mortality figures are compiled by the National Center for Catastrophic Sports Injuries Research (the Center). The Center limits its research to certain high school and college sports and does not include physical education. Over the 10 years of study from the fall of 1982 to the spring of 1992, 200 high school deaths were reported (67 direct and 133 indirect), an average of approximately 20 sports-related deaths annually (49) (see table 3-5). Direct deaths are those resulting directly from an injury sustained from participation in the skills of the sport. Indirect deaths are those resulting from a systemic failure due to exertion while participating in a sport activity or by a complication that was secondary to a nonfatal injury, such as overexertion resulting in cardiac failure or heat exhaustion.

TABLE 3-5: Reported Catastrophic Injuries from High School Sports, 1982 to 1992

	Fatal		Nonfatal			Rate/100,000 participant years	
Sport	**Direct**	**Indirect**	**Permanent**	**Serious**	**Total**	**Male**	**Female**
Cross-country	0	5	1	0	6	0.6	0.0
Football	48	52	103	113	316	2.4	—
Soccer	2	8	0	4	14	0.5	0.2
Basketball	0	35	2	2	39	0.6	0.1
Gymnastics	1	0	5	3	9	4.8	2.3
Ice hockey	1	1	4	2	8	3.6	—
Swimming	0	3	4	3	10	0.6	0.6
Wrestling	2	10	16	9	37	1.5	—
Baseball	3	5	7	6	21	0.5	—
Lacrosse	1	1	0	0	2	1.0	—
Track	9	12	6	6	33	0.6	0.0
Tennis	0	1	0	0	1	0.1	0.0
Total	**67**	**133**	**148**	**148**	**491**	**16.8**	**3.2**

SOURCE: F.O. Mueller, C.S. Blyth, and R.C. Cantue, *Tenth Annual Report of the National Center for Catastrophic Sports Injury Research*, Fall 1982–Spring 1992, (Chapel Hill, NC: University of North Carolina, 1993).

Football resulted in the greatest number of direct deaths each year among high school athletes, with an average of about five deaths (48,49). Football is associated with about five indirect deaths per year and basketball with three to four. While those three sports account for more than 90 percent of the fatalities, they are not the riskiest when judged by number of deaths per participant in a sport per year. In those terms, the riskiest high school sports for males were: gymnastics (1.75 deaths per 10,000 participants), lacrosse (0.57), ice hockey (0.43), and football (0.35). Basketball (0.63), lacrosse (0.57), ice hockey (0.43), and wrestling (0.41) had the highest rate of indirect deaths per participant. The single female fatality occurred in track.

Morbidity Data

The Scheidt study, based on 1988 NHIS data, disclosed that about 1.3 million sports/recreation injuries occur annually. Of these injuries, schools are the location for 55 percent (715,000 injuries) and the cause of 35 percent (455,000 injuries) (67). Based on a 1986 injury surveillance study, the National Athletics Trainers Association also reported that about 1.3 million injuries occur in high school sports annually (50). About 75 percent of the injuries were categorized as minor, meaning the athlete was sidelined for a week or less.

Sports injuries are reported in differently defined categories in various studies, making cross-comparisons difficult. A review of the state and epidemiological studies illustrates this problem. While the Hawaii Department of Education, Minnesota Department of Education, and Utah Department of Health all reported school sport injury estimates, the reporting categories varied tremendously (36,47,99). The Hawaii Department of Education reported that athletics and physical education represented 9 and 15 percent, respectively, of total school injuries in 1989-90. Injuries were not analyzed according to any demographic considerations. Minnesota's student survey divided school injuries into sport and non-sport categories for the 6th, 9th, and 12th grades and reporting in relation to all injuries both in and out of the school environment. School sports resulted in the following percentages of all injuries to children and adolescents: 6th grade—male 20 percent, female 17 percent; 9th grade—male 30 percent, female 27 percent;

and 12th grade—male 28 percent, female 18 percent. The Utah Department of Health data contain information on 14 different athletic activities, including physical education and organized school sports. Overall, from 1988 to 1992, sport activities accounted for 21.3 percent of the total school injuries for grades K-6 and 44.1 percent for grades 7-12. The different reporting methodologies among states obviously deter efforts to analyze studies beyond total numbers and percentages.

Epidemiological studies estimate that athletic-related injuries, including interscholastic school sports and physical education classes, account for 23 to 53 percent of all reported school injuries. Some epidemiological studies include school injury percentages and comparisons of school sports injuries to other school injuries. Boyce et al. found that athletics were associated with 26 percent of male and 16 percent of female school injuries; athletics were the leading cause of injury for males. Lenaway et al. reported that far more school injuries, 53 percent, were associated with both formally and informally organized school sports.

The few available studies that provide comparisons of in-school and out-of-school sports injuries indicate that they occur at similar rates. Zaricznyj et al. found that about half of all the sports injuries sustained by school-aged youth in Springfield, Illinois, occurred in school.

Lenaway et al. found very high percentages of sports-related injuries that increase as students progressed from elementary (40 percent of school injuries) through junior high (54 percent of school injuries) to high school (69 percent of school injuries); however, the rate of injury was highest in junior high. In contrast, the Kansas Department of Health and Education sports study, which was limited to secondary schools, found that 12th grade sports participants had the highest rate of injury (37.8 per 1,000 participants).

The studies indicate that boys generally sustained approximately twice as many injuries as girls (67 and 33 percent, respectively) (104), the difference being more prominent in high school (43). Garrick and Requa concluded that the difference, at least for organized school sports, was due primarily to participation in different sports. When catastrophic sports injury rates of boys and girls are compared, however, girls' sports actually have higher rates of injury than the same boys' sports (49,64). However, since the passage of Title IX, 20 U.S.C. sections, 1681-1688, as amended by the Civil Rights Act of 1987, Pub. L. No. 100-259, and after many of the sports studies reported here were completed, there has been an increase in female athletic participation and female teams. Moreover, the National Federation of State High School Associations Athletics Participation Survey indicates a steady increase of girls participating in sports over the last 20 years. In 1971, there were 294,015 participants and by 1993-1994 it had increased almost 10-fold to 2,124,755 participants. Accordingly, there may be a corresponding increase in girls sport injuries.

The number, severity, and type of injury depend on the athletic activity. According to the Centers for Disease Control and Prevention's (CDC) 1993 Youth Risk Behavior Survey (YRBS), only 34.3 percent of high school students had attended physical education class daily during the 30 days preceding the survey (91). Physical education classes have been reported in epidemiological studies to account for a greater number of injuries than organized school sports, in which 43 percent of high school students participate.[20] Zaricznyj et al. found that physical education accounted for 38 percent and organized school sports accounted for 15 percent of all community sports injuries. Nonorganized and unsupervised sports (40 percent) and community team sports (7 percent) accounted for the remaining 47 percent of injuries.[21] However, when par-

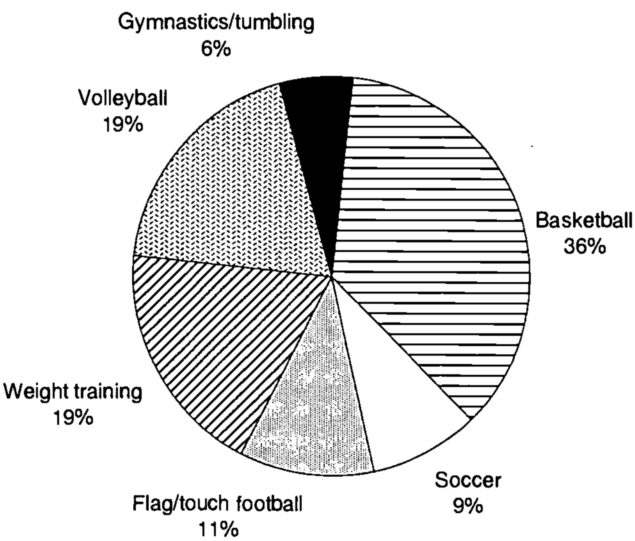
[20] In 1993-94, 3,478,530 male high school students and 2,124,755 female high school students participated in competitive sports (51).

[21] Zaricznyj et al. studied all community sports injuries, including both school sports (physical education class and organized school sports) and non-school sports (nonorganized and unsupervised sports and community sport teams (e.g., Little League)).

ticipation ratios are considered, organized sports (12 injuries/100 student years) were riskier than physical education (2.3/100). Injuries sustained in physical education occurred mainly during gym games (e.g., dodge ball and four square) and basketball, with other sports far behind. In fact, 60 percent of the basketball injuries occurred during physical education (104). In a 1990-91 study of physical education injuries in Kansas secondary schools, basketball was associated with the most injuries as well, followed by volleyball and weight training (see figure 3-5) (41).

The highest number of injuries occurred in some of the most popular sports. Table 3-6 shows the most popular sports for high school boys and girls. The Rice study of high school athletics showed that high-risk sports, in terms of both incidence and severity, are generally those expected to be so: girls' cross country (17.3 injuries per 1,000 athletic exposures), football (12.7), wrestling (11.8), girls' soccer (11.6), boys' cross country (10.5), girls' gymnastics (10.0), and boys' soccer (36.4) (64). Lenaway et al. found

FIGURE 3-5: Injuries During Physical Education at Kansas Secondary Schools School Year 1990–91



SOURCE: Kansas State Department of Education, Kansas Secondary Schools Study, 1990–91.

that the sports resulting in the most injuries by grade level were: 1) in elementary school: football, soccer, and tetherball; 2) in junior high: football, basketball, and soccer; and 3) in high school: football, volleyball, and baseball. Garrick and Requa calculated participation rates for high school sports to find that for boys, football (81 injuries/100 participants) and wrestling (75 injuries) accounted for the highest injury rates, mainly due to the greater force of impact as boys get older. The next most frequent injuries per 100 participants were for boys' track and field (33 injuries), basketball (31 injuries), soccer (30 injuries), and cross country (29 injuries). The sports particularly risky for girls were softball (44 injuries/100 participants) followed by gymnastics (40 injuries), track and field (35 injuries), cross-country (35 injuries), basketball (25 injuries), and volleyball (10 injuries).

Across studies, football was the sport associated with the greatest number of school sports injuries. In organized school sports, football accounted for four times more injuries than any other sport. Football was the leading cause of all serious injuries, fractures, injuries to the knee, and hospitalization (104), and not surprisingly, more school days were lost due to football injuries than to any other sport (41). However, it is important to note that football has the greatest number of participants.

As of 1993, only two state athletic associations, Michigan and West Virginia, recognized cheerleading as a sport, but many students are being injured while participating in this activity. CPSC estimates that in 1993 there were 15,560 emergency room visits as a result of cheerleading injuries. In the wake of highly visible stories about catastrophic injuries that occurred during cheerleading, a number of high schools across the country have limited the types of stunts that cheerleaders may attempt (49). North Dakota and Minnesota regulations governing high schools, for instance, banned the use of the pyramid after the death of a cheerleader.

Fall sports had a higher rate of injury than spring sports. One study author, Rice, postulated that this was a result of school athletes not main-

TABLE 3-6: Ten Most Popular Sports for High School Boys and Girls

Boy participants		Girl participants	
Football	928,134	Basketball	412,576
Basketball	530,068	Track & field (outdoors)	345,700
Baseball	438,846	Volleyball	327,616
Track & field (outdoors)	419,758	Softball (fast pitch)	257,118
Soccer	255,538	Soccer	166,173
Wrestling	233,433	Tennis	136,239
Cross-country	162,188	Cross-country	124,700
Tennis	135,702	Swimming & diving	102,652
Golf	131,207	Field hockey	53,747
Swimming & diving	81,328	Softball (slow pitch)	41,118

SOURCE: National Federation of State High School Associations, 1993-94 Athletics Participation Survey.

taining their conditioning over the summer months. When the intensive conditioning regimes began in preparation for the fall season, these athletes were susceptible to overuse injuries and strains (64). However, football is a fall sport and probably contributes to this higher fall number.

Comparison of studies rating the severity of sports injuries is difficult because of varying definitions of severe or serious (69). For example, Sheps and Evans recognized that some studies included sprains, strains, and dislocations while others did not. In analyzing their own data they noted that when sprains, strains, and dislocations are classified as severe injuries, approximately 56 percent of sports injuries are severe; when they are excluded, about 25 percent are severe (69). However, most school athletic injuries are not serious.

Zaricznyj et al. found in the study of sports injuries in Springfield, Illinois, that about 80 percent of sports injuries were not serious or severe; these injuries included sprains, contusions, lacerations, and superficial injuries (104). Of the remaining 20 percent of the injuries that were serious or severe injuries, about half occurred in school. Physical education produced 27 percent of serious injuries (one-third of which involved basketball), 25 percent occurred during organized school sports (more than half of which involved football), and 48 percent were accounted for by nonorganized sports. Of the serious or severe injuries (312 injuries), the most frequent included fractures (252 injuries), followed by torn ligaments (20 injuries), concussions (16 injuries), and dislocations (13 injuries). There were 65 hospitalizations, and 1.2 percent of all sports injuries were permanent (18). More than half of the serious injuries were sustained by high school students (51 percent). Junior high and elementary school students accounted for 30 and 19 percent of serious injuries, respectively.

Garrick and Requa, defining severity of injuries in terms of days missed from practice and competition, found in a study of 3,049 participants in 19 sports sustaining 1,197 injuries that nearly three-fourths (73.4 percent) of the injured student participants returned to the sport without missing more than five practice or competition days (31). Of the more serious injuries requiring x-ray examination (360 injuries), 18 percent (65) were fractures. Twenty-five athletes were hospitalized, 21 of whom required surgical procedures. Football players accounted for 16 of the 25 hospitalizations and 12 of the 21 surgical procedures, suggesting that football accounted for the majority of severe injuries. Again, football has the highest number of student participants.

Of the catastrophic injuries (fatal, permanent, and serious injuries), the National Center for Catastrophic Sports Injury Research found that in terms of raw numbers over 10 years (1982-92), football (316), basketball (39), wrestling (37), and track (33) appear to entail the most risk (49).

When these numbers are associated with participation, however, it appears that gymnastics (4.8 injuries per 100,000 participation years), ice hockey (3.6), and football (2.4) result in the most serious injuries per participating high school male athlete. Gymnastics and swimming are most commonly associated with serious injuries in participating high school female athletes.

The athletic injury studies discussed herein provide a description of the magnitude of injuries sustained by children and adolescents who participate in athletic activities. As the injury literature reflects, however, each sport presents different risks, which necessitates sport-specific summaries of the available data and a characterization of the types of injuries typically incurred in each sport (1) (see box 3-7). Most of the studies relating to specific sports injuries depend on medical or clinical reports, and incidence information is incomplete.

TRANSPORTATION INJURY DATA

Every school day, children encounter a variety of risks on their way to and from school, whether they are transported by school bus or car, ride their bicycles, or walk. Data regarding injuries resulting from crashes involving school buses, pedestrians, and bicyclists are described in this section. While there are a number of other modes of transportation to school, particularly parents driving students or older students driving themselves, no data are available to attempt to quantify these injuries.

Estimates from the few studies of injuries incurred on the journey to and from school range from 1 to 3 percent of all school injuries.[22] In general, the journey home is more dangerous than the trip to school (76,95). One study attributed this to more children walking home alone or with other children rather than with an adult (76).

Most of the risks of unintentional injury to students en route to school cannot be controlled by schools except by prevention education. Students, for example, can be taught to behave more safely and cross streets correctly, or to wear helmets when riding their bicycles and seat belts when riding in cars. School buses, however, are subject to state regulation, and school bus safety is evaluated by the U.S. Department of Transportation. Consequently, data specifically relating to school bus safety, including mortality and morbidity statistics, are available.

Sources and Limitations of School Transportation-Related Injury Data

The National Highway Safety Transportation Administration's (NHTSA) Fatal Accidents Reporting System (FARS) and General Estimates System (GES) are the primary databases for fatalities and injuries associated with school bus-related crashes, pedestrians, and bicyclists. Both systems are subject to limitations, discussed in box 3-8. The publications listed below have analyzed FARS and GES data to calculate incidence, prevalence, and trend data. The data were analyzed in the following publications:

1. NHTSA's *Traffic Safety Facts 1992;*
2. NHTSA's *Traffic Safety Facts 1992, School Buses;*
3. NHTSA's *Summary of School Bus Crash Statistics in 1990;* and
4. National Academy of Sciences' (NAS) *Improving School Bus Safety* (NRC, 1989).[23]

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[22] These estimates are based on the Hawaii Department of Education and Utah Department of Health state estimates and the NSC national estimates of school injuries. The NSC reported that about 3.1 percent of all school injuries were incurred going to and from school, 1.9 percent were motor vehicle related, and 1.2 percent were non-motor vehicle related. Because these injuries were reported to the NSC by schools, it is likely that a number of transportation injuries occurred but were not reported to the school.

[23] A provision in the federal Surface Transportation and Uniform Relocation Assistance Act of 1987 (Public Law 100-17, 204(a) (April 2, 1987)) required the Department of Transportation to contract with the National Academy of Sciences to perform a "comprehensive study and investigation of the principal causes of fatalities and injuries to school children riding in school buses and the use of seat belts in school buses and other measures that may improve the safety of school bus transportation" (55).

BOX 3-7: Common Sports Injuries in School-Aged Children

Baseball

1. At the high school level, reported injury rates ranged from 14 to 18 percent of participants.
2. Elbow and shoulder overuse injuries were the most frequent.
3. Contact and collision injuries were infrequent.
4. Most Little League (ages 5 to 14) injuries occurred when players were hit by a pitched ball (22 percent), hit by a batted ball (19 percent), while catching (14 percent), hit by a thrown ball (10 percent), or when sliding (10 percent).
5. For Little League participants, the body areas most affected were the head (38 percent) and upper extremities (37 percent), while the common types of injuries were contusions (40 percent), fractures (19 percent), and sprains (18 percent).
6. Deaths have resulted from cardiac damage secondary to non-penetrating chest trauma; 23 deaths were recorded in 5- to 14-year-olds between 1973 and 1981.

Basketball

1. In school-organized teams, the injury rate was 10.2 percent.
2. Among high school players, boys' rates of injury ranged from 6 to 31 percent and girls' from 8 to 25 percent.
3. Girls had a significantly higher rate of injury than boys (76 to 16 percent) and a higher proportion of significant injuries (18 to 8 percent).
4. The ankle, knee, and leg were most often injured. Girls appear to be at greater risk of knee injury and developing significant knee injuries, while boys had a greater chance of injuring their shoulders; there was a high prevalence of ankle sprains for both boys and girls.

Football

1. Injury experience is related to level of competition, which may in turn be related to the intensity of force generated at the time of contact.
2. Injury rates for young players (ages 8 to 14) ranged from 15 to 20 percent.
3. Injury rates for high school players ranged from 25 to 64 percent.
4. At the youth level, significant injuries occurred to 10 percent of the participants. The hand or wrist and knee were the most common injury sites, the upper body accounting for almost 50 percent of the injuries. Fractures, sprains, and contusions were the most common types of injury, and surgery was rarely required. Variables that appeared to be related to risk of injury included larger size in the oldest division, pileups after the play was completed, reinjury of an incompletely resolved prior injury, and impact with helmet.
5. At the high school level, significant injury occurred in 12 to 17 percent of participants. Lower-extremity injuries were most likely; knee and ankle were the most common injury sites. Knee injuries alone accounted for 15 to 20 percent of all injuries annually, approximately 92,000. Sprains and strains were the most common types of injury, and surgery was required for 4 percent of players. Knee injuries accounted for 69 percent of the injuries requiring surgery.
6. A high school football team can expect to average about 32 injuries per season, of which eight will be significant.
7. While more injuries occurred at practice, if corrected to numbers of injuries per exposure, games were associated with eight times the frequency of injury.
8. Tackling and blocking have been associated with the majority of catastrophic football injuries.

(continued)

BOX 3-7: Common Sports Injuries in School-Aged Children (Cont'd.)

Gymnastics

1. Injury rates for club gymnastic programs were between 12 to 22 percent.
2. The lower extremities were most often injured, but head, spine, and upper extremities were also common sites.
3. Floor exercises and tumbling accounted for the greatest number of injuries, followed by the balance beam, uneven parallel bars, and vault.
4. Half the injuries were macro-traumatic and half were due to overuse syndromes.
5. Spondylolysis occurred four times more often than in the general population.

Soccer

1. Youth soccer was associated with a low rate of injury, 2 to 5 percent.
2. Adolescent players had a higher rate of injury, 6 to 9 percent.
3. Most injuries arose from direct contact or collision with a player, the ball, or the ground.
4. Because of the running and kicking demands of soccer, overuse syndromes were also prevalent.
5. The ankle, knee, and forefoot were most often injured.
6. Significant knee sprains were not uncommon.
7. Repeated heading of the soccer ball may cause brain damage.

Track

1. Risk of injury resulted almost entirely from repetitive micro-trauma and acute strains.
2. Youth track and field athletes' (ages 10 to 15) injury rate was 50 percent; two-thirds of the injuries were related to overuse.
3. High school track athletes reported injury rates of 33 percent for males and 35 percent for females.
4. The lower leg was most frequently injured, followed by the knee, ankle, and thigh.
5. Of high school track athletes, sprinting (46 percent), distance running, activities before and after practice, and pole vaulting were most often associated with injuries.

Wrestling

1. High school wrestler injury rates from 23 to 75 percent were reported; the rate of significant injury was 15 percent.
2. Injuries arise from direct blows from an opponent, from friction on hitting the mat, falls particularly during a takedown, and from twisting and leverage forces during controlling maneuvers.
3. High school wrestlers were most likely to sustain knee sprains, back strains, and shoulder injuries; the site of injury was distributed among the upper extremities (29 percent), the lower extremities (33 percent), and the spine and trunk (34 percent).
4. More injuries occurred in competition (43 percent) than in practice (37 percent) or scrimmages (20 percent).
5. "Cauliflower ears" were decreasing in frequency due to use of head gear and improved mat surfaces, and severe neck strains and fractures appeared to be controlled by the strict rule against slams.

SOURCE: American Academy of Pediatrics, Committee on Sports Medicine and Fitness, *Sports Medicine: Health Care for Youth Athletes, 2nd ed.*, P.G. Dyment (ed.) (Elk Grove Village, IL, 1993); Goldberg, B., et al., Injuries in Youth Football. Pediatrics, 1988;12:122–132; Mueller, F.O., and Cantu, R.C., *Annual Survey of Catastrophic Football Injuries 1977–1992* (Chapel Hill, NC: 1993).

BOX 3-8: Sources and Limitations of School Transportation-Related Injury Data

Estimating the extent of school-related travel in transportation and deaths is difficult because fatalities and injuries are not reported by purpose of travel. Estimates can be made, however, from the sources of data that are discussed below, remembering that each source has substantial limitations. None of them differentiates whether the injuries were incurred during school-related travel.

The National Highway Traffic Safety Administration's (NHTSA) Fatal Accidents Reporting System (FARS) maintains fatality census data on crashes involving a traveling motor vehicle and resulting in the death of a vehicle occupant or non-motorist within 30 days. FARS is a collection of state-reported data. Since 1975, 50 states, the District of Columbia, and Puerto Rico have submitted qualifying data from police crash reports, state vehicle registration files, state drivers' license files, state highway departments, vital statistics, death certificates, coroner/medical examiner reports, hospital medical reports, and emergency medical service reports, and those data are the primary source for mortality data related to crashes involving school buses, pedestrians, and bicycles. Data, however, vary significantly from state to state. For instance, because the definition of school bus differs among the jurisdictions registering vehicles, there is no accurate number of school buses that transport students and no truly accurate number of school-related crashes.

FARS data are reported for ages 0–20+ at age intervals of 0–4, 5–9, 10–14, 15–19, and 20+. In the discussion below, school-aged children and adolescents in terms of FARS data include ages 5–19. FARS includes data on school bus-related crashes, pedestrians, and bicyclists; however, the information is limited for the purposes of this report as the reason for travel at the time of the crash is not indicated. Thus, it is indeterminable whether the death of a school-aged child was also school related.

In 1988, NHTSA established the General Estimates System (GES), the injury counterpart to FARS. Unlike FARS, however, GES estimates are based on a national probability sample of about 45,000 police crash reports collected each year rather than census data. To qualify for the GES sample, a police accident report must be completed for the crash; the crash must involve at least one traveling motor vehicle and property damage, injury, or death must result. Like FARS, GES includes information on school bus-related crashes, pedestrians, and bicyclists. The actual difference between estimates and true values varies depending on the sample selected. GES pedestrian and bicycle injury data are particularly problematic. The relatively low numbers reported for pedestrian and bicycle injuries result in high standard errors. For example, NHTSA calculated that 1992 GES estimated a generalized standard of error of 400 for 1,000, 1,000 for 5,000, and 1,500 for 10,000.

FARS and GES define school buses by body type as opposed to purpose. Thus, even after a bus is sold by a school to another organization (e.g., a church), it is still classified as a "school bus." NHTSA estimated, however, that approximately 81 percent of bus occupant fatalities from 1977 to 1990 involved school buses providing school-related group transport.

SOURCE: Office of Technology Assessment, based on U.S. Department of Transportation, National Highway Traffic Safety Administration. *Traffic Safety Facts 1992*, September 1993; U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts 1992: School Buses*, U.S. Department of Transportation, National Highway Traffic Safety Administration, *School Bus Safety Report*, May 1993; U.S. Department of Transportation, National Transportation Safety Board, *Summary of Selected School Bus Crash Statistics in 1990*, 1993

The NAS study *Improving School Bus Safety* reviewed and analyzed school bus-related crash data on fatalities and injuries from 1982 to 1988 (55).

School Bus-Related Crashes Injury Data

School buses transport about 25 million students to and from classes and school-sponsored activities (55). Although most crashes involving school buses are minor, catastrophic crashes resulting in student fatalities and serious injuries do occur every year (98). A comparison of school bus-related crash and passenger car crash fatalities and injuries among school-aged children suggests that school buses are much safer than other forms of transportation used to take students to and from school. NHTSA reports roughly 650,000 fatal traffic crashes in the past 16 years, of which less than 0.4 percent were classified as school bus-related (95). Of these crashes, 90 percent were school bus-type vehicles and 10 percent were other vehicles providing school-related group transportation (95). In fact, NAS estimates that occupant fatalities per mile for school buses are approximately one-fourth those for passenger cars (55).[24] Moreover, given the typical school bus size and weight of more than 10,000 pounds, injuries are more likely to occur to the occupants of a passenger car involved in a crash with a school bus than to the occupants of the school bus (93). Nonetheless, the incidence of school bus-related crash injuries indicates that improvements in school bus safety are essential (55).

While standards passed in 1977 (see box 3-9) have improved the crashworthiness of school buses, national information regarding school bus-related crashes remains sparse. Despite efforts to improve the reporting of school bus crashes, according to the 1989 NAS study on school bus safety, the availability and quality of data have not improved much. The NAS study, the most extensive study of school bus injuries and attendant safety measures, characterized national statistics as inadequate and claimed that its efforts to collect valid national data were seriously hampered by lack of a standard definition among states of school bus crashes or school bus-related crashes. As a result, NAS recommended that "NHTSA work with the states, and other interested organizations to upgrade and standardize school bus crashes data collected by the states" (55). Nevertheless, NAS concluded that the imperfect national and state reports can be used in attempts to understand the magnitude of the problem and where, when, and to whom such crashes occur.

Mortality data

The major studies of fatalities in school bus-related crashes are listed in table 3-7A. The NAS study reports that about 50 school-aged children are fatally injured in school bus-related crashes each year, including school-aged pedestrians and passengers. About 75 percent of the deaths, 37 to 38 children, were pedestrians in loading zones around school buses: of those, approximately 24 were struck by school buses, two were killed by vehicles operated as school buses, and 11 to 12 were killed by other vehicles in the bus loading zone.[25] Approximately 12 school-aged children were killed each year while riding to and from school or school-sponsored activities on school buses or on vehicles used as school buses. Between 1982 and 1986, 60 school bus passengers were killed in 26 separate accidents; of those, 48 were passengers under 20 years old (55). Students aged 10 to 14 were reported to account for 32 percent of all school bus passenger fatalities, followed by students aged 15 to 19 (27 percent) and 5 to 9 (17 percent); the remaining 24 percent were over 20 and most likely drivers of school buses. Fatality rates by age, however, were not presented. It may be that students aged 10 to 14 are more likely to be riding the school bus because more parents drive

[24] According to the NSC's *Accident Facts* (1993), the difference between school bus and passenger car fatality rates was even more pronounced (57). NSC reported that in 1989-91 the average fatality rate per hundred million passenger miles was 0.02 for school buses and 1.05 for passenger cars.

[25] The most recently published FARS estimates of school bus-related crash fatalities and injuries are available in NHTSA's *Traffic Safety Facts* 1992; except for pedestrians, the data are not published by age so the number of school-aged children injured is not known (94). This data indicated that in 1992 an estimated 124 people were killed in school bus-related crashes, of which 83 were occupants of other vehicles, 29 were pedestrians, 9 were school bus passengers, 2 were bicyclists, and 1 was a school bus driver. Of the 29 pedestrians struck by a school bus, 21 were of school age, 50 percent of whom were 5-6 years old.

BOX 3-9: School Bus Safety

In 1977, NHTSA issued regulations that mandated stricter safety for school buses, including requiring seat belts for post-1977 buses of 10,000 pounds or less but not for those of more than 10,000 pounds. The rationale was that buses weighing more than 10,000 pounds are heavy, strong, and well-padded, and their seats are "compartmentalized" to protect passengers in the event of a crash. The NAS report concluded that the 1977 standards greatly improved the crashworthiness of school buses and that the estimated 10 percent of pre-1977 school buses still operating should be replaced by buses manufactured after 1977 as soon as possible.

Additional safety measures and their efficacy, particularly for seat belts, are continually under debate. In recent years, a number of school districts and two states have mandated that all buses ordered after a certain date be fitted with seat belts. New York requires all school buses manufactured after June 30, 1987, and operated within the state to be equipped with seat belts; New Jersey similarly directs that all school buses purchased after September 1, 1992, have seat belts. These laws differ in that New York does not require actual use of the belts whereas New Jersey does. In commenting on the cost and effort of equipping buses with safety belts, NAS concluded that because children are at greater risk of being killed in loading zones (i.e., boarding or leaving a bus) than onboard the bus, a larger share of the total effort should be targeted at improving the safety of school bus loading zones.

The federal government also developed Highway Safety Program Manual #17, *Pupil Transportation*, which provides standards governing school bus driver licensing and training, loading and unloading of students, bus maintenance and inspection, operation, and crash records. The guidelines, which were revised in 1991, are voluntary and, as such, not enforceable; incentive programs or policies are offered to encourage states to adopt the guidelines. Technical assistance is also provided to state transportation officials in reviewing their school bus safety programs.

SOURCE: Office of Technology Assessment, based on U.S. Department of Transportation, National Highway Traffic Safety Administration, *School Bus Safety Report*, May 1993.

younger children to school or more adolescents drive themselves to school. Moreover, children who walk to neighborhood elementary schools may be bussed to larger and more centralized middle schools

The studies also reveal that for the general population (not limited to school-aged children), occupants of other vehicles and nonoccupants, primarily pedestrians, are at greater risk of experiencing a fatality than school bus passengers: 56 percent of the total fatalities involved occupants of other vehicles; 33 percent involved nonoccupants, including pedestrians and bicyclists. School bus passengers represented the remaining 11 percent of the overall fatalities (95).

All studies based on NHTSA's FARS data concluded that school-aged children are at greatest risk of fatal injury while they are getting on or off, as compared to while they are riding, the school bus. It also appears that student pedestrians are at a far greater risk of being struck by their own bus than by another vehicle (98). An average of roughly two-thirds of all pedestrians killed were struck by a school bus (95,98), and 6 percent were struck by vehicles operating as a school bus. In these crashes, "inattention" and "failure to yield" were the contributing factors most often cited by police. Thirty percent of pedestrian fatalities were killed by other vehicles in school bus-related crashes (95). For drivers of other vehicles, the common contributing factors reported by police were "failing to obey signs, safety zones, or warning signs on vehicles," "passing where prohibited," and "driving too fast."

NHTSA further examined the 1983-92 data by time of day. Significantly, more school-aged pedestrians were killed in school bus-related crashes in the afternoon (73 percent) than in the morning (27 percent); 42 percent were killed between 3:00 and 4:00 p.m. alone.

TABLE 3-7A: Annual Passenger, Pedestrian and Bicyclist Fatalities in School Bus-Related Crashes, by Study

Study	Annual total number of fatally injured people in school bus-related crashes	School-aged school bus (or vehicle used as school bus) passengers fatally injured	School-aged pedestrians fatally injured	School-aged bicyclists fatally injured
1992 NHTSA's Traffic Safety Facts (FARS)	124	9	29	2
1983–1992 NHTSA's Traffic Safety Facts (FARS)	157	—	30	—
1977–1990 Summary of Selected School Bus Crash Statistics (FARS) (average)	179	11–12	34	—
1982–1988 NAS Report on Improving School Bus Safety (FARS) (average)	149	12	37–38	3.2
1991–1992 National Safety Council	110	10	25	—

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA); *Traffic Safety Facts 1992,* September 1993; U.S. Department of Transportation, National Transportation Safety Board, *Summary of Selected School Bus Crash Statistics in 1990*, 1993; National Research Council, Transportation Research Board, Committee to Identify Measures that May Improve the Safety of School Bus Transportation, *Improving School Bus Safety* (Washington, DC: National Academy Press, 1989); National Safety Council, *Accident Facts* (Itasca, IL: 1993).

Risk of school bus-related crash pedestrian death appears to be linked to age; younger children are more likely than older children to be fatally injured in school bus-related crashes. NAS determined that 54 percent of the school-aged pedestrians killed in school bus-related crashes were 5- to 6-year-olds and similarly, NHTSA reports that half of all school-aged pedestrians killed by school buses from 1983 to 1992 were between 5 and 6 years of age (55,95). Seven- and 8-year-olds also accounted for a significant proportion of fatalities (23 percent). Fatalities caused by non-school bus vehicles were more equally distributed among all ages; the NAS report concluded that age-specific safety devices for school buses, particularly for young pedestrians, may reduce the occurrence of fatalities.

The NSC also provides annual school bus-related fatality and injury data (57). NSC surveys state departments of education and state traffic authorities each year for information from which it generates national estimates of school bus-related crash injuries. These estimates were generated despite the fact that in 1992, 13 states did not submit data. The NAS study noted that because of the absent information and varying definitions under which state data are collected, the NSC data underestimated the actual numbers (55).

Morbidity data

In a 1977 report to Congress, William Coleman, then Secretary of Transportation, stated that:

> Wholly reliable information on school bus crashes is not readily available on a national basis. This is particularly true for nonfatal injury crashes, and even more so for crashes in which no injury is present. The information deficiency exists with respect to descriptive statistics as well as to accident-injury causation data; and it stems from both inadequate investigation at the accident site and the lack of formal

and systematic data collection and synthesis process to produce aggregated information.

More than 10 years later, the NAS report recognized a similar lack of national data from which to develop a certain number or even an adequate estimate of injuries suffered by children in school bus-related crashes (55). There is tremendous underreporting and inconsistent reporting of school bus-related crash injuries. For example, some states include all school bus passengers when reporting injury statistics, while others report only those involving students (55). The major studies of school bus-related crash injury data are presented in table 3-7B.

To compensate for the lack of reliable data on nonfatal injuries, NAS developed a school bus-related injury estimate using selected state data. School bus-related crash data from 14 states were aggregated and analyzed to develop a national estimate of 19,000 injuries, 9,500 of which were to school bus passengers (see figure 3-6). By using the same data, average characteristics of school bus-related crashes were identified. The report concluded that of the total injuries, 50 percent were sustained by school bus passengers, of which 5 percent were incapacitating.[26] The majority of the school bus-related crashes were minor. A review of a few state crashes and of the National Crashes Sampling System revealed that about half of the injuries suffered in school buses affected the head, face, and neck (55).

About 800 additional injuries suffered by pedestrians in school bus-related crashes were reported. In contrast to fatality estimates, far fewer pedestrians than school bus passengers were injured, but pedestrian injuries were typically more severe. An estimated 20 percent of the pedestrian injuries were incapacitating, compared to 5 percent for passengers. The NAS report stated that research aimed at reducing student transportation injuries should focus on school bus loading zones and additional protections available for students in these zones.[27] Figure 3-6 shows the mortality and morbidity data.

Estimates of injuries on school buses from 1990 GES data were higher than the NAS estimates. The 1990 GES data indicated about 17,500 injuries to school bus passengers; 1,000 (5.9 percent) of these were severe. An additional 4,500 injuries were sustained by occupants of other vehicles; 500 (11.1 percent) of these were severe. Thus, NHTSA's GES data estimates a total of 22,000 injuries as compared to the NAS estimate of 19,000 injuries.

The body locations and types of injuries to students in school bus-related crashes are not reported on a national level. Tables 3-8 and 3-9 provide police reported injury data collected by the New York Department of Motor Vehicles for bus passengers and for pedestrians on the way to and from a stopped school bus (55); they illustrate the type and severity of injuries sustained in these crashes. The figures include all school bus passengers—students and adults. The head, face, and eyes were the predominant sites of injury: about 58 percent of the incapacitating, 65 percent of the non-incapacitating, and 34 percent of the possible injuries were to the head or face. The most frequent types of incapacitating injury were concussion (27.0 percent), fracture/dislocation (24.7 percent), and severe bleeding (14.7 percent). Among those who sustained non-incapacitating injuries, more than half complained of contusion/bruise and 30 percent minor bleeding. Of injuries to pedestrians going to and from stopped school buses in New York (table 3-9), the lower extremities accounted for approxi-

[26] Incapacitating injury is defined as "any injury that prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred" (NRC, 1989). It includes, but is not limited to, severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, being unconscious at or when taken from the accident scene, and being unable to leave the accident scene without assistance (55).

[27] Injury data from the Utah Department of Health support the conclusion that students are at greater risk in the loading area than in the school bus. From 1988 to 1992, 102 students were reportedly injured on school buses and 177 in school bus loading zones. Among grades K-6, school bus and bus loading areas injuries accounted for 0.38 and 0.57 percent of total grades K-6 school injuries. The incidence of injury of school bus and bus loading area injuries of students in grades 7-12 was 0.2 and 0.6 percent, respectively.

TABLE 3-7B: Annual Passenger and Pedestrian Injuries in School Bus-Related Crashes, By Study

Study	Annual or average annual total school bus-related crash injuries	School bus passenger injuries	Occupant of other vehicle injuries	Pedestrian injuries
NHTSA's Traffic Safety Facts (GES) 1992	23,000	11,000	9,000	1,000
National Safety Council 1991–1992	14,000	8,300 students	—	200
Summary of School Bus Crash Statistics (GES) 1990	17,500 (5.9 percent)[a]	—	4,50 (11.1 percent)[a]	—
NAS Report on Improving School Bus Safety (average) 1982–1988	19,000	9,500 (5 percent)[a]	—	800 (20 percent)[a]

[a]Percentage of severe or incapacitating injury

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Traffic Safety Facts 1992*, September 1993; U.S. Department of Transportation, National Transportation Safety Board, *Summary of Selected School Bus Crash Statistics in 1990*, 1993; National Research Council, Transportation Research Board, Committee to Identify Measures that May Improve the Safety of School Bus Transportation, *Improving School Bus Safety* (Washington, DC. National Academy Press, 1989); National Safety Council, *Accident Facts* (Itasca, IL: 1993).

mately one-third of all injuries. A significant number of head injuries occurred for both the incapacitating and non-incapacitating injuries, about 30 and 27 percent respectively.

Pedestrian Injury Data

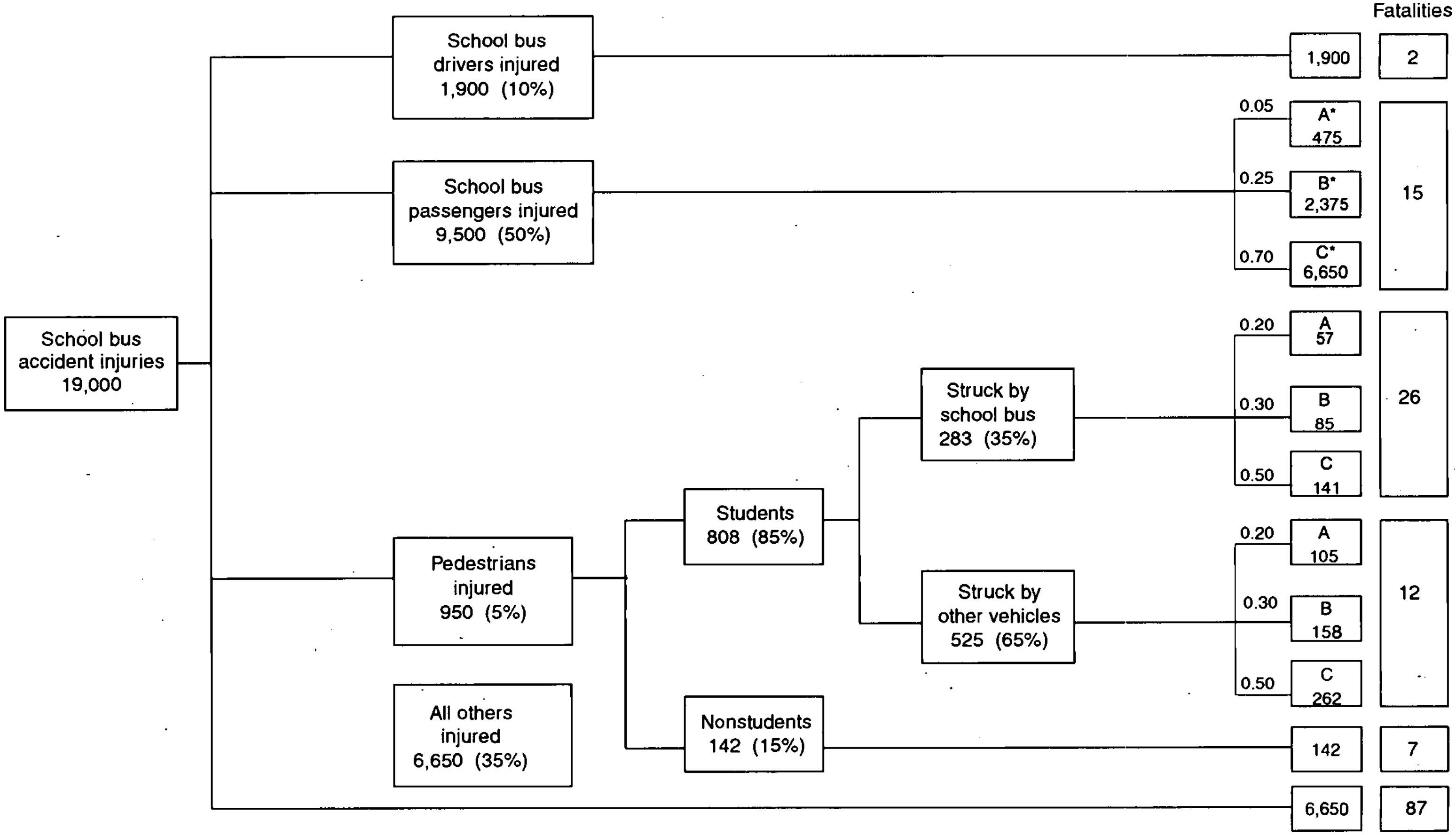
Fatalities and injuries occur to student pedestrians while walking to and from school. NHTSA collects school-aged pedestrian mortality and morbidity data, *but the information does not indicate if travel was school related.* However, databases that record pedestrian injuries by age and time provide some estimates to indicate the scope of the problem. At OTA's request, NHTSA generated time of day data for school-aged pedestrians using 1992 FARS and GES data (96,97). Assuming students typically travel to school between the hours of 6:00 a.m. and 9:00 a.m. and travel home between 2:00 p.m. and 5:00 p.m., some estimates can be made and age and time trends identified. Table 3-10 presents the number of school-aged pedestrians fatally and nonfatally injured during these times students are typically going to and from school. While the data provide an instructive illustration of pedestrian injuries for age groups and time of day, for OTA purposes, the data probably represent overestimates since they include school-aged pedestrians who were not necessarily on the way to or from school.

One hundred and twenty-one school-aged pedestrians were fatally injured during the two school travel time periods; an additional 9,600 suffered nonfatal injuries. Thus, for each death of a school-aged pedestrian during these hours, there were about 79 injuries. Fifty percent of the fatalities were to the 5- to 9-year-olds alone; however, the 10- to 14-year-olds suffered 54 percent of the nonfatal injuries. Of particular note, 60 percent of the injuries suffered by 10- to 14-year-old pedestrians occurred between 2:00 p.m. and 5:00 p.m. Twice as many fatalities and injuries occurred in the afternoon than in the morning.

Bicyclist Injury Data

In 1992, 40 percent of the bicyclists killed in traffic crashes were between the ages of 5 and 15. The fatality rate for this age group was 7.2 per million population—more than 2.5 times the rate for all bicyclists (94). There are about 1 million school-aged children injured on bicycles and skates annually (67). Schools are the reported location for 2.7 percent and the cause of 1.4 per-

FIGURE 3-6: Annual Fatalities and Injuries in School Bus Accidents



*Level A: Incapacitating injury. Any injury that prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred. Inclusions: Severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconscious at or when taken from the accident scene; unable to leave accident scene without assistance; and others. Exclusion: Momentary unconsciousness; and others.

Level B: Non-incapacitating evident injury. Any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the accident where the injury occurred. Inclusions: Lump on head, abrasions, bruises, minor lacerations; and others. Exclusion: Limping (the injury cannot be seen); and others.

Level C: Possible injury. Any injury reported or claimed that is not a fatal injury, incapacitating injury, or non-incapacitating evident injury. Inclusions: Momentary unconsciousness. Claim of injuries not evident. Limping, complaint of pain, nausea, hysteria, and others.

SOURCE: National Research Council, Transportation Research Board, Improving School Bus Safety (Washington, DC: National Academy Press, 1989).

TABLE 3-8: Police-Reported Injuries Sustained by Passengers in School Bus Accidents in New York (1980–1986)

	Injury severity (%)		
	A[a] (N=170)	B[b] (N=971)	C[c] (N=2,619)
Location of most severe physical complaint			
Head	33.4	31.7	27.9
Face	10.0	32.7	6.1
Eye	14.1	1.4	0.0
Neck	5.9	1.1	12.6
Chest	2.4	2.0	3.2
Back	1.8	1.1	9.3
Shoulder/upper arm	4.1	3.1	5.9
Elbow/lower arm/hand	7.1	8.7	4.8
Abdomen/pelvis	4.7	0.5	2.7
Hip/upper leg	5.9	2.9	2.7
Knee/lower leg/foot	6.5	12.8	10.0
Entire body	1.8	0.4	5.9
Unspecified	2.3	1.6	8.9
	100.0	100.0	100.0
Most severe physical complaint			
Amputation	0.6	0.0	0.0
Concussion	27.0	0.0	0.0
Internal	9.4	0.0	0.0
Minor bleeding	6.5	30.9	0.0
Severe bleeding	14.7	0.0	0.0
Minor burn	0.6	0.6	0.0
Moderate burn	0.0	0.0	0.0
Severe burn	0.0	0.0	0.0
Fracture/dislocation	24.7	0.0	0.0
Contusion/bruise	0.6	53.0	0.0
Abrasion	0.6	15.5	0.0
Complaint of pain	12.9	0.0	77.7
None visible	2.4	0.0	16.9
Unspecified	0.0	0.0	5.4
	100.0	100.0	100.0

(continued)

TABLE 3-8: Police-Reported Injuries Sustained by Passengers in School Bus Accidents in New York (1980–1986) (Cont'd.)

Victims' physical and emotional status			
Unconscious	4.7	0.0	0.0
Semiconscious	11.8	0.0	0.0
Incoherent	2.9	0.0	0.0
Shock	3.5	1.1	1.3
Conscious	77.1	98.9	98.7
	100.0	100.0	100.0

[a]Level A injury means an incapacitating injury that "prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred. Inclusions: severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconscious at or when taken from the accident scene; unable to leave accident scene without assistance; and others. Exclusion: Momentary unconsciousness; and others."
[b]Level B injury means a non-incapacitating evident injury that includes "any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the accident where the injury occurred. Inclusions: Lump on head, abrasions, bruises, minor lacerations; and others. Exclusion: Limping (the injury cannot be seen); and others."
[c]Level C injury means a possible injury that includes "any injury reported or claimed that is not a fatal injury, incapacitating injury, or non-incapacitating evident injury. Inclusions: Momentary unconsciousness. Claim of injuries not evident. Limping, complaint of pain, nausea, hysteria; and others."

SOURCE: National Research Council, Transportation Research Board, *Improving School Bus Safety* (Washington, DC: National Academy Press, 1989).

TABLE 3-9: Police-Reported Injuries Sustained by Pedestrians Going to and from Stopped School Buses in New York (1980–1986)

	Injury severity (%)		
	A[a] (N=56)	B[b] (N=130)	C[c] (N=192)
Location of most severe physical complaint			
Head	30.4	26.9	11.5
Face	0.0	9.2	1.6
Eye	1.8	0.0	0.0
Neck	1.8	0.0	1.0
Chest	0.0	1.5	1.0
Back	0.0	2.3	5.7
Shoulder/upper arm	7.1	4.6	5.2
Elbow/lower arm/hand	5.4	10.0	6.8
Abdomen/pelvis	1.8	0.0	4.2
Hip/upper leg	5.4	13.1	18.2
Knee/lower leg/foot	35.6	30.8	37.0
Entire body	8.9	0.8	5.2
Unspecified	1.8	0.8	2.6
	100.0	100.0	100.0
Most severe physical complaint			
Amputation	5.4	0.0	0.0
Concussion	12.5	0.0	0.0
Internal	3.6	0.0	0.0
Minor bleeding	3.6	19.2	0.0
Severe bleeding	10.7	0.0	0.0

(continued)

TABLE 3-9: Police-Reported Injuries Sustained by Pedestrians Going to and from Stopped School Buses in New York (1980–1986) (Cont'd.)

Minor burn	0.0	0.0	0.0
Moderate burn	0.0	0.0	0.0
Severe burn	0.0	0.0	0.0
Fracture/dislocation	60.6	0.0	0.0
Contusion/bruise	0.0	53.1	0.0
Abrasion	0.0	27.7	0.0
Complaint of pain	3.6	0.0	82.8
None visible	0.0	0.0	14.6
Unspecified	0.0	0.0	2.6
	100.0	100.0	100.0
Victims' physical and emotional status			
Unconscious	5.4	0.0	0.0
Semiconscious	7.1	0.0	0.0
Incoherent	1.8	0.0	0.0
Shock	10.7	5.4	4.2
Conscious	75.0	94.6	95.8
	100.0	100.0	100.0

[a]Level A injury means an incapacitating injury that "prevents the injured person from walking, driving, or normally continuing the activities he was capable of performing before the injury occurred. Inclusions: severe lacerations, broken or distorted limbs, skull or chest injuries, abdominal injuries, unconscious at or when taken from the accident scene; unable to leave accident scene without assistance; and others. Exclusion: Momentary unconsciousness; and others."

[b]Level B injury means a nonincapacitating evident injury that includes "any injury, other than a fatal injury or an incapacitating injury, that is evident to observers at the scene of the accident where the injury occurred. Inclusions: Lump on head, abrasions, bruises, minor lacerations; and others. Exclusion: Limping (the injury cannot be seen); and others."

[c]Level C injury means a possible injury that includes "any injury reported or claimed that is not a fatal injury, incapacitating injury, or nonincapacitating evident injury. Inclusions: Momentary unconsciousness. Claim of injuries not evident. Limping, complaint of pain, nausea, hysteria; and others."

SOURCE: National Research Council, Transportation Research Board, *Improving School Bus Safety* (Washington, DC: National Academy Press, 1989).

cent of these injuries (67). The majority of these injuries occur on the street (42 percent) or at home (32 percent). However, there are no estimates of the number of children and adolescents that ride their bicycles to school. Some children or adolescents injured on the street or at home may have been en route to school. The 1992 FARS and GES data, described above relating to pedestrians, were also used to generate data for bicyclists from 6:00 to 9:00 a.m. and 2:00 to 5:00 p.m. (96,97) (see table 3-11).

Thirty-nine school-aged bicyclists died and 7,000 were injured during these times. More 10- to 14-year-olds were killed or injured than the other age groups; however, they are also the age group more likely to be riding bicycles. Bicycle-related deaths and injuries of school-aged children likewise occurred more often in the afternoon. GES injury data estimates by age for the morning hours were too low to publish due to the large sampling error (95 percent). Nevertheless, GES data estimate a total of 1,200 injuries in the morning, which—when compared to the 5,800 injuries in the afternoon—indicates that school-aged children and adolescents are four to five times more likely to be injured in the afternoon. Increased fatalities and injuries in the afternoon may be attributable to the number of children riding bicycles for recreation as well as for transportation (5). Thus, these data, as they relate to the school environment, are undoubtedly over-inclusive.

TABLE 3-10A: 5- to 18-Year-Old Pedestrians Killed on Monday Through Friday, September 1991–May 1992

Age	6 a.m. to 9 a.m.	2 p.m. to 5 p.m.	All other times	Total
5-9	19	42	90	151
10-14	17	27	68	112
15-18	6	10	87	103
Total	42	79	245	366

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Fatal Accident Reporting System 1992 Data for Pedestrians and Pedalcyclists Ages 5–18* (Washington, DC: 1994).

TABLE 3-10B: 5- to 18-Year-Old Pedestrians Injured Monday Through Friday, September 1991–May 1992

Age	6 a.m. to 9 a.m.	2 p.m. to 5 p.m.	All other times	Total
5–9	900	1,800	3,700	6,400
10–14	1,400	3,800	2,900	8,100
15–18	1,000	700	1,400	3,100
Total	3,300	6,300	8,000	17,600

All estimates subject to large sampling error due to small sample size. 95 percent confidence interval.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *General Estimates System 1992 Data for Pedestrians and Pedalcyclists Ages 5–18* (Washington, DC: 1994).

Head injuries sustained when bicycle riding are the foremost cause of fatal injuries. At least 70 to 80 percent of fatally injured bicyclists of all ages had significant head injuries (5). In a study of children less than 16 years old admitted to Maryland hospitals in 1982 for bicycle crash-related injuries, 97 percent were of school age (5 to 15 years). Forty-five percent of the children had head injuries (fractured skull, concussion, or other brain injury). It has been well documented that these injuries could be prevented or ameliorated if the children wore helmets. One case control study estimates that helmets reduce the risk of head injury by 85 percent in emergency room cases (78).

UNINTENTIONAL INJURY CONCLUSION

Unintentional injury is a significant health problem that follows children and adolescents into the school environment. Nonetheless, there is no systematic, organized process for collection of national data on school injuries. Data are collected by many different organizations, public and private, but national data are not available systematically from any identified source. More detailed analysis of existing databases such as NHIS and NEISS by location (school) and age (school-aged persons) could yield some national estimates. OTA identified at least four states that collect school injury data (Arizona, Hawaii, South Carolina, and Utah). Arizona, South Carolina, and Utah have used this data to identify particular injury problems in their respective states and to create specific school injury prevention programs. Epidemiological studies provide a more detailed study of injuries occurring at school; however, caution must be used in generalizing results from local epidemiological studies to national and state school populations. Despite studying different student populations in various geographic locations, most epidemiological studies reached similar conclusions regarding school injuries. Thus, while conclusions about the relative safety of schools are sound, there is a deficiency of reliable school-related unintentional injury data.

In terms of unintentional injury, play at playgrounds and sports are the most risky school activities. While national data provide some estimates on the incidence of these injuries, state and epidemiological studies provide some data on the circumstances of the injuries. Although other injuries that occur in the school building also represent a significant number, little is known about them. Classrooms, laboratories, shop facilities, stairs, and hallways all present some risks of injury to students. While some studies have collected some data on these locations, not much is known about the circumstances of the injuries.

TABLE 3-11A: 5- to 18-Year-Old Bicyclists (Pedalcyclists) Killed on Monday Through Friday, September 1991–May 1992

Age	6 a.m. to 9 a.m.	2 p.m. to 5 p.m.	All other times	Total
5–9	1	9	29	39
10–14	4	15	35	54
15–18	2	8	15	25
Total	7	32	79	118

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *Fatal Accident Reporting System 1992 Data for Pedestrians and Pedalcyclists Ages 5–18* (Washington, DC: 1994).

TABLE 3-11B: 5- to 18-Year-Old Bicyclists (Pedalcyclists) Injured Monday Through Friday, September 1991–May 1992

Age	6 a.m. to 9 a.m.	2 p.m. to 5 p.m.	All other times	Total
5 to 9	*	1,400	1,900	—
10 to 14	*	3,300	3,900	—
15 to 18	*	1,100	1,000	—
Total	1,200	5,800	6,700	13,800

*Estimates by age for this time period are too small to publish. All estimates subject to large sampling errors due to small sample sizes. For example, the 95 percent confidence interval for an estimate of 1,400 pedalcyclists is 1,400 ± 900.

SOURCE: U.S. Department of Transportation, National Highway Traffic Safety Administration, *General Estimates System 1992 Data for Pedestrians and Pedalcyclists Ages 5–18* (Washington, DC: 1994).

INTENTIONAL INJURY

In recent years, school violence has been a priority for both the executive and the legislative branches (25,79,80,81,82). Support for research at the National School Safety Center (NSSC) (see box 3-10), and the launching in October 1993 of a Division of Violence Prevention at the CDC (see box 3-11) are two initiatives that reflect this interest. In late 1993, Clinton Administration officials also formed a multidisciplinary Interdepartmental Working Group on Violence Prevention with a Subgroup on Schools.

Burgeoning congressional concern and general public inquiry about risks related to intentional injuries have precipitated calls for more accurate measurements of violence and more extensive evaluation of new public health and school security technological interventions in many of the nation's school districts (see box 3-12). By early 1994, the National School Boards Association (NSBA) and the Children's Defense Fund issued reports outlining some risks of school violence in their respective profiles of public and privately supported reduction and prevention strategies (20,58).

Even though the media, parents, students, law enforcement officials, and many other observers have taken it as axiomatic that school violence has increased during the past few years, no comprehensive national surveillance system tracks injuries from intentional violence in the school environment. Nevertheless, authorities are being urged to take action. The 103d Congress submitted 61 bills on school violence. States have spent considerable sums of monies allocated for schools on efforts to decrease violence in school; for example, the New York City Board of Education spent $1,009,000 in the 1992-1993 school year on metal detectors, such as walk-through x-ray equipment, hand-held detectors, and mats (74). Given the costs associated with these policy decisions, it is necessary to evaluate the data that provide the basis for these decisions for accuracy, certainty, and limitations associated with them.

This section considers the following questions related to the information available on intentional injury: What are the data on intentional injuries in school in the United States? How are the data obtained and reported?

National representative samples and surveys of school districts as well as diverse local school records provided the main source of primary data on the risk of interpersonal violence and suicidal behavior in the school environment (61). For the most part, however, these instruments are relatively new. For instance, 1993 is the first year for which data singling out violence-related behaviors and risks on school campuses have been integrated into the Youth Risk Behavior Survey (YRBS). The YRBS is an instrument of the Youth Risk Behavior Surveillance System (YRBSS) developed by the CDC and conducted

BOX 3-10: National School Safety Center

Founded by presidential mandate in 1984, the National School Safety Center (NSSC) is the product of a partnership between the U.S. Department of Justice and the U.S. Department of Education. Located near its affiliate—Pepperdine University—in Westlake Village, California, the NSSC's mission has been twofold: to provide education about the problem of school safety and to serve as a clearinghouse for data on trends in violence and innovative programs dealing with school crime prevention. Ronald D. Stephens, the Center's Executive Director, and his staff work very closely with the Centers for Disease Control and Prevention and local school districts. "We're generally working with a different school system somewhere each week around the country with some type of school crime and violence behaviorally related issues," Stephens acknowledges.

In addition to its more active participation in the construction of local programs to tackle school violence and safety concerns, the NSSC issues a set of publications on a regular basis to inform the public, educators, government officials, and law enforcement officials about national and local developments. Two examples of recent publications are *School Safety Update* and *Gangs in School*. The Center's publications have carried articles ranging from "Weapons: A Deadly Role in the Drama of School Violence" to "Dealing with Diversity."

SOURCE: Office of Technology Assessment, 1995.

BOX 3-11: Division of Violence Prevention, National Center for Injury Control and Prevention

Although the Division of Violence Prevention at the Centers for Disease Control and Prevention (CDC) was officially founded in the fall of 1993, the investigation of factors leading to violence-related morbidity and mortality has been a part of CDC's research agenda for more than a decade. The Violence Epidemiology Branch was initially founded at CDC in 1983. With the more widespread acceptance of a public health focus on violence, which stresses the role of prevention as well as the influence of various social, economic, and behavioral factors, a multidisciplinary team of social and behavioral scientists, epidemiologists, and educators has worked to bring visibility to homicide, domestic and spousal abuse, suicide, and other forms of interpersonal violence through the Division of Violence Prevention. Implicitly, this has also entailed greater attention to the improvement of national and local surveillance systems to track the epidemiology of violence-related injury patterns in American society.

In the aftermath of the 1979 Surgeon General's Report "Healthy People" and a Surgeon General's "Workshop on Violence and Public Health" in 1985, both of which helped to lay the groundwork for later goals to reduce rates of intentional injury, interpersonal violence among youth has remained a top priority. It became clear to researchers at the CDC that rising rates of homicide and suicide among youth reflected the need to address pressing social problems through more specific public health interventions at younger ages. For this reason, schools are currently targeted as a site for public health education, and the CDC's Division of Violence Prevention runs such programs throughout the country. The Division for Violence Prevention also collaborates with other centers at the CDC and federal agencies in the design of the Youth Risk Behavior Surveillance System, which measures the incidence of weapon carrying and other violence-related behaviors among youth. Most recently, members of the Division of Violence Prevention collaborated with the National School Safety Center as well as the U.S. Departments of Education and Justice in a retrospective analysis of violence-related deaths on school campuses during the past two years.

SOURCE: Mark L. Rosenburg and Mary Ann Fenley, Editors, *Violence in America: A Public Health Approach*. (New York and Oxford, England: Oxford University Press, 1991); "New Directions in Violence Prediction: The Public Health Approach." *Violence and Victims* 3 (1988): 285–288.

BOX 3-12: Technology and Violence Prevention

Students in urban, suburban, and rural schools across the nation find themselves confronted with a barrage of new technological devices employed to deter the bringing of weapons, such as guns, knives, and razors, into the school environment. Walkie-talkies, video cameras, metal scanners, large airport-size metal detectors, and x-ray machines, as well as the equipment that transports security personnel among and within school campuses, represent a few of the strategies currently implemented in some districts. For instance, one suburban community in Washington state recently purchased bullet-proof vests for its security personnel after several shooting incidents on or near school campuses.

Technologies to deal with the incidence of school violence have recently been adopted in many school districts across the nation. The National School Safety Center reports that the proportion of large school systems employing metal detectors somewhere in their districts increased from 25 percent to 70 percent in two years.

Students at one urban school arrive for a daily metal scanning. During the entire process, which takes about a minute and a half per student, pupils place their bookbags on a scanning machine before stepping on a floor metal detector unit. The student then proceeds through a metal detector. If the light turns red on the metal detector unit, he or she is then asked to step aside and is rescanned to detect the source of the problem. Each detector can cost school districts up to $20,000 for a state-of-the-art airport-type unit. Although policy analysts and researchers still do not agree about the effectiveness of metal scanning as a deterrent to weapon carrying, the fact remains that the deployment of technologies to stem violence has changed the character of the school day for many of America's students.

SOURCE: Office of Technology Assessment, 1995.

every two years at the national, state, and local levels. It continues to rank among the most cited sources of information on weapon carrying and physical fighting among the school-aged population.

Sources and Limitations of Intentional Injury Data

OTA has identified three kinds of data bearing on intentional injury in the school environment: incident reports compiled at the school level, crime statistics, and health/vital statistics. The national sources described in box 3-13 were chosen because they were devised as parts of ongoing surveillance efforts.

Definitional inconsistencies, underreporting, and poor baselines characterize each data source. OTA found a number of school crime logs and security reports that failed to identify a police number and official offense in the school district's records, illuminating the problem of definitional inconsistencies. Even when school districts encourage the use of standardized forms to collect information on risks and injuries, parts of the form detailing crucial demographic characteristics, such as age, grade, and race/ethnicity, are often left out of the final product or report. Underreporting results from the failure of many school officials and districts to report criminal acts to police authorities. Finally, researchers have only recently started collecting much of the available data and too little is known from previous years to discern increases or decreases in violence. Together, these handicaps contribute to the poor quality of data that obscures the public's perception and identification of trends in risks of intentional injury in the school environment.

Incidence and Distribution of Intentional Injuries

School-Associated Violent Deaths

Homicide and suicide are ever-present threats for children of school age. Every single killing, especially of children, occurring in school justifiably receives considerable public attention. Cur-

BOX 3-13: National Sources of School-Related Intentional Injury

School Data

Incident reports obtained from local school officials constitute the bulk of school-based data. Forms are usually completed indicating that a particular student was involved in an incident where an injury or crime took place, but forms often are not filed. While some school officials keep detailed records for their own purposes, OTA found that many local school authorities failed to report criminal incidents to a district or state-level office. This reluctance or inaction stemmed from fears among principals and teachers of the stigmatization of a particular school or group of students. These problems were illustrated by a crisis at the New York City Board of Education in July 1994, when the Chancellor of Schools rejected a school security report after discovering that 400 schools had failed to report a single incident (Dillon, 1993). A subsequent investigation identified more than 1,300 unreported incidents. Although South Carolina has passed a legislative directive mandating the reporting of school crime to the state's Department of Education, most local school districts have only recently begun to encourage the use of a standardized form to report an incident.

Crime Statistics

The Department of Justice sporadically collects data on school crime in traditional crime surveillance statistics on the federal level. The Bureau of Justice Statistics' annual victimization survey *Criminal Victimization* in the United States provides some pertinent interview information related to school participants 12 years of age and older for: percentage of incidents inside school building or on school property; whether self-protective measures were taken; whether strangers or nonstrangers were involved; whether a weapon was used; race/ethnicity and gender of victim; and the number of offenders. The 1991 victimization survey results stated that 12 percent of violent crimes occurred in school buildings.

The Department of Justice's **School Crime: A National Crime Victimization Report** (1989), an extension of the National Crime Victimization Survey, provides data from a representative sample of 21.6 million students aged 12 to 19 years. According to the survey, 2 percent of respondents indicated that they had been victims of violent crimes at school, such as aggravated assault, robbery, and rape.

Health/Vital Statistical Data

The National Center for Health Statistics estimates the number of intentional injury fatalities that occur to the school-aged population; however, it does not have a systematic mechanism to link injuries in youth aged 5 to 18 in the school environment. The lack of coordination with state-level efforts has handicapped this process. OTA has identified two federal surveillance mechanisms at the CDC that provide some epidemiological information on intentional injury in the school environment on an ongoing basis:

Youth Risk Behavior Surveillance System. The YRBSS is the most comprehensive national initiative to monitor the prevalence of behaviors that result in intentional injuries (such as physical fighting and weapon carrying) among youth. It has of four components: national school-based surveys; state and local school-based surveys; a national household-based survey; and a national college survey. First administered in the spring of 1990, the school-based components of the YRBSS will be implemented biennially during odd-numbered years to national, state, and locally representative samples of 9th to 12th graders.

Two of the YRBSS's principal limitations are that it does not cover students below the 9th grade and relies on student self-reports to characterize trends in physical fighting and weapon carrying. Not all state and local education agencies conduct the YRBSS, and response rates in some states and cities that do participate in the YRBSS have at times been poor.

(continued)

BOX 3-13: National Sources of School-Related Intentional Injury (Cont'd.)

National Adolescent Student Health Survey (NASH). Administered and developed by the American School Health Association in partnership with the Association for the Advancement of Health Education and the Society for Public Health Education, Inc., the NASH provides data on student perceptions of physical fighting, strategies to resolve conflicts, victimization (one of the few studies that covers sexual assault in detail), weapons possession, and participation in violence prevention programs. During the 1987–88 school year, the survey was administered to 3,789 students attending 176 schools in 20 states.

School Health Policies and Programs Study (SHPPS). The SHPPS is a part of the CDC's recent effort to provide a better nationwide profile of public and private school policies in the area of violence. Based on national surveys (voluntary) of 780 schools in 480 school districts that support a comprehensive health program, the SHPPS collects data from state, school district, and school personnel who make or enforce policies related to violence in schools. Data will be used to measure 18 national health objectives and National Education Goal 6 for violence-free schools. The study omits elementary schools, except where they have 7th graders.

Data from the first set of surveys was collected during the first half of 1994. Results will be available late in 1995. When the results are reported individual schools will not be singled out. Instead, the data will be available in aggregate form. Officials at the CDC hope that this new survey instrument will help create better measurements of efforts to reduce and prevent violence in schools.with more national data on the influence of particular policies on incidence levels.

rently, the NSSC is the only comprehensive source of information on these incidents, which it compiles from analysis of newspaper clippings (box 3-10). Since July 1992, the NSSC has collected data on "school-associated violent deaths," defined as any homicide, suicide, or weapons-related death in the United States in which the fatal injury occurred either on the school grounds, or on the way to an official school-sponsored event. The NSSC identified 45 school associated violent deaths for the 1993-94 school year and 53 for 1992-1993 (72).

Since the NSSC culls its estimates from news clippings received from various clipping services and other periodicals, it may underreport the exact numbers of cases. Given the limitations of using newspaper clippings as a data source, the CDC's Division of Violence Prevention initiated in 1992 an ongoing collaborative study with the NSSC and the Departments of Justice and Education to collect death certificate data and other school and Justice Department data. Their objective is to verify the number and circumstances around violent deaths at school, on school property, or during school-sponsored events.

Preliminary results from their search of 8,000 newspapers show that 105 violent deaths occurred on school campuses over the two school years (1992-93 and 1993-94): 87 homicides, 18 suicides, and five ruled "unintentional" through the legal process (39). This averages to about 44 homicides and 9 suicides per year or 53 "school-associated violent deaths." Their finding is the most reliable estimate available because they followed up on every report submitted from the NSSC.

Students in school do not appear to be at a great risk for homicide or suicide. The 53 "school-associated violent deaths" constitute a small fraction of the relative mortality of the school-age population, with the 3,889 homicides and 2,151 suicides occurring in children aged 5 to 19.

Suicide, the eighth leading cause of death in the United States, is the third leading cause of death for young people 10 to 19 years old (88). Between 1970 and 1984, suicides in this group rose 55 percent. Though school does not appear to be a prominent site for the commission of suicide, the parents, students, staff, school health officials, and researchers interviewed by OTA stated that depression and general emotional highs and lows are frequently part of the school and adolescent experience at all levels.

Prior to the CDC collaborative study, the most comprehensive national representative sample of risks for suicide in schools has come from the YRBSS and a few surveys of high school behavior (61). Data from several sources indicate that suicide and attempted suicide are problems for some school-age youth, even though schools have not been a common location for commission of these acts (60,88). The 1993 YRBSS noted that 24.1 percent of students surveyed admitted having "thought seriously" about suicide during the 12 months preceding the survey (91).

Furthermore, about 9 percent of students admitted that they attempted suicide during the 12 months that preceded the survey and about 3 percent of students indicated that they needed medical treatment for an injury, poisoning, or overdose as a result of their attempt. Gender differences were noted, as 5 percent of males in the sample had attempted suicide compared to 13 percent of females; however, males are more likely to die in a suicide attempt than females.

Weapon Carrying

After motor-vehicle-related injuries, injury due to firearms is the second leading cause of death in children ages 5 to 19; together they dwarf all other causes of death for which data are available. In 1992, there were 5,260 firearms-related deaths of children ages 5 to 19, which include deaths due to intentional injuries (i.e., firearm-related homicides and suicides) and deaths due to unintentional injuries involving firearms. In 1992, the number of intentional injuries due to firearms in school-aged children (about 3,280 firearm-related homicides, and 1,430 suicides) far exceeded the number of unintentional injuries due to firearms (470 deaths).

However, children are much less likely to die from firearm-related injuries in school than out of school. During two recent school years (1992-93 and 1993-94), researchers identified an average of 53 "school-associated violent deaths"—homicides, suicides, and unintentional weapon fatalities—per year, almost all of which were related to firearms.

Estimates of the number of weapons in school vary widely (see box 3-14). According to the NSBA and the Center to Prevent Handgun Violence, anywhere from 100,000 to 135,000 guns are brought into schools every day (18,58,59). In Cleveland, 22 percent of boys in a sample of 5th, 7th, and 9th graders admitted owning a gun to protect themselves from threats and insults (68). New York City school security officials confiscated 65 guns from students on school grounds barely four months into the 1993-94 academic school year (74). The State of Florida has admitted similar problems, with a 61 percent increase in handguns between the 1986-87 and 1987-88 school years (18). With recent shootings in many urban, rural, and suburban communities, concerns about weapons in schools will probably remain a top priority for local school boards.

In some communities, even young school-aged children have access to weapons. According to the NSBA, 63 percent of gun-related incidents on school grounds occurred among high school students and 24 percent among junior high school students, while elementary school and preschool students constitute 12 percent and 1 percent, respectively, of total incidents (58). These disparities are consistent with other local studies among students on their general access to weapons, as well as with the demographics of where weapons are found by school authorities. One-third of Seattle's 11th graders acknowledge that they have "easy" access to guns (15). Of the 1,249 weapons found in Virginia public schools during the 1991-92 school year, 853 were recovered from middle school students (18).

Students carry weapons to school for a variety of reasons (68,92,100). Iowa education officials report that 23 percent of their high school students who carry a weapon to school do so for protection (32). In the 1993 MetLife national sample, 22 percent of boys and 4 percent of girls said that they had brought weapons to school

BOX 3-14: Weapons Confiscated on School Campuses

Weapons possession is tracked very differently among the U.S. school systems that keep such statistics. This area is rife with definitional problems because many school districts report incidents but not necessarily the type of weapon involved. It is often impossible to discern from local school board incident reports whether a gun, knife, club, or other weapon precipitated disciplinary action against a student.

Characterization of the seriousness of weapons in schools, however, varies from location to location. In some areas, such as South Carolina, the Department of Education reported that possession of weapons was the most frequently occurring offense. For other school districts, including New York City, Los Angeles Unified, and most Connecticut districts, weapons offenses—although not the number one offense—ranked high on school crime lists, preceded by vandalism, assault, harassment, larceny, and burglary, many of which involved weapons possession as a secondary offense.

The difficulty in tracking weapons possession in schools stems primarily from the fact that many school districts report the most serious offense as the primary incident. Therefore, weapons are ignored as a secondary offense and consequently are not often reported in school incident data. In South Carolina, for example, from June 1992 through May 1993 there were 626 incidents (21 percent) with weapons possession as the most serious offense. However, the total number of incidents involving weapons was 1,055, 36 percent of all school incidents reported in South Carolina during the 1992–93 school year. Other schools districts, such as Los Angeles Unified School District, further classify weapons incidents to distinguish between assaults and possessions and also to determine at what level such incidents are occurring (whether elementary, junior high school, or senior high school). Still, the newness of mandatory school crime reporting legislation in South Carolina and other areas means that good baselines are in process of being created to measure trends in these offenses and incidents.

Although the diversity in mechanisms and definitions used to collect statistics on weapons possession has made it impossible to generalize trends outside a given school district or state, most school districts reporting to OTA stressed that knives and other sharp objects, such as "box cutters" (instruments used to cut boxes and commonly found on students who have after school jobs where such instruments are used), are the most commonly employed or confiscated weapons. Perhaps this is due to the accessibility and low cost of knives. In the 1992–1993 school year, South Carolina's Department of Education reported that approximately 42 percent of weapons incidents involved knives or sharp objects. Handguns and other firearms are usually the second most popular choice of weapons among students in California, Connecticut, and New York, where more comprehensive statistics have been kept.

SOURCE: Office of Technology Assessment, 1995.

(45). When asked to state a reason for weapon carrying, 66 percent answered that it was to "be accepted" and 49 percent emphasized "self-defense to and from school." Such statistics and statements provide an important social context for rates of weapon carrying across the country.

The motivation for and access to guns outlined in MetLife's results and the recent sample of Seattle's 11th graders are consistent with levels of weapon carrying reported in the most extensive national and regional/local investigations at the CDC. According to the YRBSS, 22 percent of high school students admitted to carrying a weapon (i.e., a gun, knife, or club) to school in the preceding 30 days, and almost one-third of these students (8 percent) admitted to carrying a gun (91). However, due to repeat offenders, there are around 92 weapon-carrying incidents monthly per 100 students (91). Important gender and racial breakdowns accompanied these results. The YRBSS showed that male students were much more likely to carry a weapon to school than females. Black students were much more likely to carry a weapon to school than Hispanic or white students—29 percent of black students carried a weapon to school in the preceding 30 days compared to 24 percent for Hispanics and 21 percent for white students.

A number of shootings have drawn attention to the problem of guns in school, but it is important to note that knives and razors are the weapons most likely to be found on students in most areas sampled by the YRBSS (40). According to MetLife, 55 percent of students bring knives or switchblades to school (45). Suburban Prince George's County, Maryland (near Washington, D.C.), has charted a 94 percent increase in knife possession during the past year. One in five New York City high school students recently reported carrying a weapon anywhere at least once during a 30-day period: 16 percent carried knives or razors, and 7 percent carried handguns (89). Significantly, the same survey also found that weapon carrying of all types was lower inside the building and going to and from school than at other locales outside the school environment. Twelve percent of students admitted carrying a weapon inside the school building, with 10 percent of that group reporting that they carried knives or razors and 4 percent indicating that they carried handguns.

Increasingly, metal detectors and scanners are being employed to prevent weapons from being carried into schools. The NSBA survey in 1993 found that 15 percent of all districts reported using metal detectors (58). In its examination of different localities, the NSBA found that 39 percent of urban districts, 10 percent of suburban, and 6 percent of rural districts reported using metal detectors.

There are some empirical and anecdotal data on the effectiveness of metal detectors in preventing the entrance of guns, knives, and weapons into school buildings, but to date there have been no controlled studies evaluating the effectiveness of metal detectors in reducing weapon-related violence and injuries in schools. In June 1992, researchers from the CDC, the New York City Board of Education, and the New York City Department of Health administered a questionnaire to students as part of an effort to examine violence-related attitudes and behaviors among public high school students (89). The study found that students who attended schools with metal detectors (about 18 percent of all high school students) and students who attended schools without metal detectors were equally as likely to carry weapons anywhere (22 percent versus 21 percent, respectively). There was a difference reported, however, with respect to carrying weapons into the school building: 7.8 percent of students who attended schools without metal detector programs reported that they had carried a weapon inside the school building during the 30 days preceding the survey, while 13.6 percent of those who attended schools with such programs indicated that they had carried weapons into the building.

As the authors of this study point out, these findings do not include data on intentional injury rates in school, and do not have "pre" and "post" measures of weapon-carrying rates in schools that were participating in the metal detector program at the same time of the survey. Nor do the study's results indicate how underreporting by students at schools with metal detector programs may have influenced the findings. The forthcoming 1995 results from CDC's first question related to carrying weapons inside the school building (and not "anywhere" as in previous YRBSS local and national samples) should help to establish important baselines for further school-based research.

Assaults

Assaults present a major problem for investigations of intentional injury among students in the school environment. The lack of a precise definition of "assault" in much of the literature makes it difficult to sort out which behaviors precipitated the labeling of an offense as an assault, particularly among school data (44). This problem primarily reflects the lack of standardization in local and national reporting of school crime in either medical or crime reports. As one observer at an OTA workshop explained, two types of documents about violent incidents often exist within schools: an informal categorization based on a principal's subjective decision and an official police document with a crime report. A principal's report of a physical fight in school, in this context, may not meet the national crime definition for an assault but may be considered such by school authorities.

The characterization of physical—and to a lesser extent, verbal and psychological—assaults has been perceived as a major problem in understanding school violence by most researchers. The NSBA estimates, however, that assaults rank at the top of a list of more than 16,000 violent incidents reported on a daily basis in school buildings (58). Of the more than 2,000 school districts reporting to the NSBA survey about violence, 78 percent noted that they have had problems with student-on-student assaults during the past year. This response came from 91 percent of urban districts, 81 percent of suburban districts, and 69 percent of rural districts.

New York City and Los Angeles, for example, are two cities that keep assault statistics in Divisions of School Security run by administrators who maintain surveillance databases based on official police categories. Yet such databases often suffer from underreporting at the building level. Trends observed for various assault offenses in NYC and Los Angeles and other areas are reported in table 3-12.

Physical fighting

Physical fighting is often cited as an index of how young people in the United States deal with conflict in the school environment (40). It has also been highlighted in the literature as an important correlate of weapon carrying. Data on the prevalence and severity of physical fighting among school-aged youth have emerged from recent national and local surveys. The YRBSS found that 4 percent of all students reported that they had been in at least one physical fight that resulted in an injury requiring medical treatment during the 12 months that preceded the survey (40). Among students who fought, about half indicated that they had fought one time, another quarter of respondents indicated that they had fought two or three times, and about 10 stated that they fought at least four times.

Researchers have also identified differences in incidence rates for physical fighting with regard to gender. The 1993 national YRBSS, for instance, identified a higher rate of physical fighting among males than females (91). A rate of 173 incidents per 100 students occurred among males during the previous 12 months, while females were engaged in 96 incidents per 100 students, or almost twice as many incidents among males as females.

Social attitudes about physical fighting among younger adolescents in the school environment are generally under-researched, but several studies document the extent to which weapon carrying is viewed as a deterrent to physical fighting among older adolescents (46,68,100). A 1992 study of violence-related attitudes and behaviors among a representative sample of 9th- to 12th-grade public high school students in New York City found that students who carried a weapon at school were more likely than others to believe that they could protect themselves from fights if they flashed a weapon, such as a club, knife, or gun (89). When compared with all students, those who brought a weapon to school during the 30 days preceding the survey were more likely to believe that threatening others with a weapon (21 versus 44 percent for all students) and carrying a weapon (20 versus 48 percent) were effective ways to avoid a physical fight. A significant percentage of students who carried weapons to school also reported that their families would support their decision to protect themselves from physical attack even if it meant using a weapon (44 versus 68 percent) (89).

Physical fighting appears to be more prevalent among out-of-school youth than in-school youth. According to a CDC study, there is a difference in the prevalence of certain risk behaviors among adolescents aged 12 to 19 years, based on school enrollment status. The CDC conducted a survey of adolescents aged 12 to 19, between April 1992 and March 1993. The survey found a higher percentage of adolescents "out of school" who indicated that they had participated in a physical

TABLE 3-12: Violent Offenses in Selected Areas, July 1992–July 1994

Type of offense	1988–89	1989–90	1990–91	1991–92	1992–93	1993–94
Florida (Dade)						
Homicide		0	0	1	3	2
Sexual battery[a]		34	50	24	23	23
Assault[b]		1,889	1,999	2,125	1,947	2,060
Weapon possession[c]		393	468	558	568	571
Sex offense[d]		128	131	133	159	126
New York City						
Homicide	0	1	2	2	2	
Assault	1,356	1,684	1,260	1,880	2,643	
Weapon possession[e]	1,854	1,891	2,045	2,416	2,444	
Sex offense	78	94	65	121	91	
Gang Fight	1	0	5	1	0	
Los Angeles						
Homicide			1	1	2	0
Assault			68	74	66	107
Assault with a deadly weapon			285	292	236	361
Weapon possession[f]			863	926	845	1,300
Sex offense[g]			53	87	70	119
South Carolina						
Homicide				0	0	2
Aggravated Assault				300	251	410
Weapon offense				540	626	917
Sexual offense[h]				27	44	52

[a]including attempts
[b]including threat of or physical harm
[c]including brass knuckles/firearms, etc.
[d]including lewd behavior/indecent exposure
[e]including weapons that are not illegal, but prohibited by New York City Board of Education
[f]including gun and knife replicas and other weapons
[g]including misdemeanors and felonies
[h]including forcible and non-forcible

SOURCE: Office of Technology Assessment, 1995.

fight in comparison to students who stayed in school: 51 percent of out-of-school youth, compared with 44 percent of in-school students. Furthermore, 23 percent of out-of-school youth admitted carrying weapons, 7 percent higher than the number of in-school students admitting such behavior. In New York City, 8 percent of high school students sampled entered into a physical fight inside their school buildings compared to 25 percent of students who reported engaging in fights anywhere (89). Fourteen percent reported being threatened inside the school, as compared with 36 percent who reported that they were threatened anywhere.

Violence or threatened violence in school is a reflection of violence elsewhere in the community. Officials from the NSSC often stress this point in their reports on school crime and violence, as they also acknowledge that schools exist in the context of a broader community (59,90). Although rates for physical fighting may on some level be reflective of a high degree of interpersonal violence within the school environment, students generally seem to enter conflict to a lesser extent when in school.

Gangs

The preponderance of research about physical fighting has revealed gangs as an important factor in interpersonal violence in some schools (16,38). According to the Northern California-based Center for Safe Schools and Communities, "youth gangs of all races have increased by 200 percent in the last five years and female gangs now represent 10 percent of all gang groups in the nation" (17). Some scholars suggest that gangs can be important places of refuge and identity formation for students in some areas of the country (2,16). Trend data on gangs are sparse, but gang membership in school may begin as early as the 4th grade for many students (34).

Many school districts do not keep consistent statistics on gang activity, which may lead to underreporting. It is also unclear in many instances whether definitions of gang-related problems in the school environment are limited to the building, or its immediate vicinity, or whether they include students going to and from school, as well. The available epidemiological evidence suggests that many of the injuries resulting from gang activity occur away from school (17). Of students sampled in the National Crime Victimization Survey, 79 percent said that no gangs were present in their schools. Of those students reporting the presence of gangs, 35 percent indicated that they feared an attack on school grounds, as compared to 18 percent of students who reported no gang activity (92). A recent analysis of the Los Angeles Police Department, which reports 400 gangs with a total membership of 60,000 in the city, notes that less than 1 percent of injuries stemming from gang rivalry during 1991 took place at public schools or in public parks (38). Approximately 60 percent of urban school districts have also reported gang activity to the NSBA, as suburban and rural districts also find themselves grappling with gang violence (58). Since schools are one of the most important places for socialization of young adults who can wind up in gangs, gang membership rates should continue to be cause for concern.

INTENTIONAL INJURY CONCLUSIONS

OTA has found that for two prominent causes of death—homicide and suicide—students are at less risk in schools than out of schools. An average of 44 homicides occurred annually among students in the school environment during the 1992-1993 and 1993-1994 school years—about 1 percent of all homicides for that age group in 1992. With respect to suicide, an average of 9 occurred in schools annually over these two years, or less than 1 percent of all suicides committed in that age group in 1992.

OTA's investigation of the epidemiological and educational literature as well as school-based records reveals very few intentional injury surveillance mechanisms in local school districts to monitor school violence. The National Research Council's 1993 report, *Understanding and Preventing Violence,* singled out "violent events in schools" as an area in which "high priority be placed on modifying and expanding relevant statistical information systems" (53). OTA has found these shortcomings in most school districts, a fact made clear by the identification of only three states that could supply comprehensive data on school crime and violence covering the past few years. Fortunately, local and national public health officials appear to be moving toward public policies that recognize the value of more systematic data collection efforts on intentional injury as an important basis for prevention.

The poor quality of data on the risk of intentional injury in the school environment makes it impossible to discern the impact and severity of risks from violence, in a national context and in many local districts. Furthermore, the lack of adequate baseline data for particular behaviors in school, such as weapon carrying, is a local and national problem, which results in not being able to determine trends for intentional injury in schools. These problems stem from the reluctance of school authorities to report crimes to the appropriate education officials and crime authorities. OTA identified three states that require reporting of school crime; additional states have voluntary reporting. Most policymakers rely on self-report surveys (often with poor response rates) to characterize trends in school violence.

INJURY IN SCHOOL CONCLUSIONS

With respect to the leading causes of unintentional and intentional injuries among school-aged children, schools are a relatively safe environment. The primary reason for this is that schools are not typically the location of the leading causes of injury deaths to school-aged children—motor vehicle crashes, homicide, and suicide. For fatal injuries such as homicide and suicide, about 1 percent of deaths for persons aged 5 to 19 occur at schools. One study of severe injuries, using data from the National Pediatric Trauma Registry (NPTR), found 3 percent of the injuries admitted to participating trauma units occurred at schools (29). However, for certain types of injuries, such as athletic injuries, the percentage of injuries incurred in schools may be higher than outside the school environment.

Table 3-13 presents the approximate number of fatalities due to injury that occur at schools each year. However, fatalities represent only the tip of the injury pyramid, as most students who are injured do not die of their injuries. A population-based study of childhood injuries in Massachusetts showed that for each death of a child (19 years of age or under), there were 45 hospitalizations and 1,300 emergency room visits (30). The number of injuries treated elsewhere or not treated was not known. These ratios are probably greater in relation to school injuries—additional analysis of the data showed that injuries at school resulted in fewer hospitalizations than injuries incurred elsewhere (63). Moreover, leading causes of mortality incidence may not reflect the leading cause of morbidity incidence (70). Thus, to determine the extent of school injury incidence, both quality mortality and morbidity data must be developed and examined.

Currently, mortality data are generally more comprehensive and reliable than morbidity data because death records are maintained by all states; mortality data are compiled annually from death certificates at both the state and national level. Yet these statistics are not detailed enough to analyze unintentional fatalities trends at schools because the location of the death may not be reported. Morbidity data are even less complete, often precluding detailed analysis of the circumstances under which injuries occur. Moreover, data on school injury outcome, rehabilitation, and long-term disability are virtually

TABLE 3-13: Selected Fatalities Occurring in School[a]

Related activity/factor	Approximate number of fatalities per year
Playground	8–9[b]
Sports	20[c]
School bus-related crash (passengers)	12[d]
School bus-related crash (pedestrians)	37–38[e]
School bus-related crash (bicyclists)	3.2[f]
Homicide	44[g]
Suicide	9[g]

[a]These fatalities represent only the most prominent reported fatalities from the sources cited. It is likely that other fatalities occurred in schools from other causes.

[b]CPSC's 1990 *Playground Equipment-Related Injuries and Deaths* reported 276 fatalities over the 16-year study period. About 50 percent of the deaths were of children under the age of six. School-aged fatalities, therefore, averaged eight to nine a year. Importantly, these are equipment-related fatalities only.

[c]F.O. Mueller, C.S. Blyth, and R.C. Cantue, *Tenth Annual Report of the National Center for Catastrophic Sports Injury Research*, fall 1982–spring 1992 (Chapel Hill, NC: University of North Carolina, 1993). This number does not include fatalities which occurred during physical education.

[d]National Research Council, Transportation Research Board, Committee to Identify Measures that May Improve the Safety of School Bus Transportation, *Improving School Bus Safety* (Washington, DC: National Academy Press, 1989).

[e]Ibid.

[f]Ibid.

[g]National School Safety Center and CDC, average of the total numbers of homicides and suicides found in the 1992–93 and 1993–94 school years.

SOURCE: Office of Technology Assessment, 1995.

nonexistent, making the determination of injury severity and impact nearly impossible. The disparity in the quality of national mortality and morbidity data is due in part to the absence of mandatory reporting for the external cause of injury and school as a location category on injury coding forms.

In 1985, the National Research Council report *Injury in America* concluded that "most of the data sources currently available for the study of injury have serious inadequacies" (54). The information has not improved much during the intervening time (70). Although morbidity and mortality estimates are available for injuries incurred by school-aged children, data on school-related injuries are wanting. Definitional inconsistencies, the lack of accurate baselines, underreporting, and the absence of a national—and, in most cases, state-level surveillance system—complicate the characterization of trends in injuries at school and undermine public health intervention efforts to stem the impact and severity of risk factors related to school injuries.

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Illness in School 4

In 1992, school-aged children missed more than 154 million school days from illnesses associated with acute respiratory and digestive conditions and infectious diseases—285 days for every 100 students (14). Illnesses are responsible for more lost school days than injuries; in 1992, illnesses accounted for roughly 75 percent of the approximately 175 million lost school days from short-term conditions (both injuries and illness).

Although illnesses accounted for fewer fatalities than injuries in this age group, three illnesses in 1992 were among the leading causes of death: cancers, congenital anomalies, and heart disease. In that same year, fatal poisonings claimed the lives of 191 children, the respiratory diseases pneumonia and influenza led to the deaths of 189 school-aged children, and infection with the human immunodeficiency virus (HIV) contributed to the deaths of 152. These figures attest to the potential impact of illnesses on children's health.

Many of the causes of illness in children can be found in the school environment (249). This chapter divides health hazards leading to illness into two categories: environmental hazards and infectious disease hazards.[1] Most people think of a collection of toxic agents lumped together as "environmental hazards," and many of these are present, at some level, in schools. These are, primarily, chemicals, fibers, and radiation. Infectious disease hazards arise from a variety of pathogenic microbial agents, such viruses, bacteria, or fungi.

NATURE OF ENVIRONMENTAL HEALTH HAZARDS AND INFECTIOUS DISEASE

This report groups health hazards leading to illness into four categories: environmental health hazards that originate from 1) school materials, 2) indoor air, and 3) school location, in addition to 4) infectious diseases. These categories depend most heavily on the source of exposure, removing the focus of attention away from particular hazards and towards finding common strategies for preventing or reducing threats to health (see table 4-1). This classification scheme contains considerable overlap, such as asbestos, which can be considered a school material as well as an indoor air problem. Conversely, pesti-

[1] As used throughout this report, risks are probabilistic estimates of the likelihood of an adverse health outcome in response to, in this case, an environmental agent. Hazard is the agent that generates the risk.

TABLE 4-1: Environmental Hazards in School

Nature of hazard	Type of hazards	Source	Route of exposure	Possible effect	Remediation or prevention strategies
School Materials: Lead Pesticides Cleaners, solvents, paints Art supplies Lab materials	Chemical/biological	Intentional appearance in school Result of inadequate handling, use, storage, labeling	Dermal/oral	Exposure at high concentrations: poisoning, chronic illness	Proper handling, use, storage; better education
Indoor Air Quality: Asbestos Radon Other air contaminants	Radiation/chemical/biological	Unintentional appearance in school; result of inadequate ventilation	Respiratory	Chronic lung disease Sick building syndrome	Redesign; maintain heating, ventilation, and air conditioning
School Location: Electromagnetic fields Hazardous waste sites Noise	Radiation/chemical/injury	Siting and location of school	All	Results from low-level exposure: chronic illness/loss of hearing	Move school/prudent avoidance
Infectious Disease	Biological	Communicable pathogens	Respiratory/oral	Infectious disease	Hygiene

SOURCE: Office of Technology Assessment, 1995.

cides present indoor air problems but are considered by OTA as school materials.

School materials are brought to the school environment for use in the classroom (e.g., art supplies, chemicals used in laboratories), and for maintenance and cleaning of the school building and school grounds (e.g., solvents, pesticides). Such school materials can present health risks as a result of improper handling and use or accidents. Moreover, there are concerns that even proper use of some chemicals can increase the risk of chronic diseases, especially cancer. Adverse health effects from exposure to school materials can be limited by better education of supervisory individuals and the proper handling, use, labeling, and storage of these materials.

Indoor air hazards are agents that accumulate and concentrate in the indoor air of the school facility. They include asbestos, which is present in some building materials; radon—a naturally occurring radioactive gas; combustion products; various volatile compounds; and non-infectious biological materials. Many indoor air quality problems can be remedied by properly maintaining the ventilation system in the school building, although some require more drastic steps.

School location can bring students into contact with hazards, for example, when a school is located near a hazardous waste site. The dangers of school location can be managed by relocating students or reduced by taking steps to avoid excessive exposure to the hazard (e.g., cleaning up a hazardous waste site).

Finally, infectious diseases are spread by social interactions, some of which occur in school. Infectious diseases can be controlled by better prevention (e.g., use of vaccines), earlier identification of an outbreak of disease, and improved hygiene.

NATURE OF ENVIRONMENTAL HEALTH DATA

OTA evaluated the kinds of data collected on environmental hazards in schools. Two types of information are needed to associate an agent found in the school environment with illness. First, there must be evidence that exposure to the agent can produce the observed effect. Second, there must be evidence that the student was exposed to the agent in the school environment. When these two conditions are met, there remains the task of showing it was the in-school exposure and not an exposure elsewhere that caused the illness.

To estimate health risks, scientists and public health officials use a variety of different kinds of information. As described in chapter 2, the information can be the reports of monitoring and surveillance by physicians and public health officials, surveys of health effects and exposures, or more detailed investigation into the causes of illness. These disparate types of information rely on distinct and established methods of collection and interpretation. Despite these differences and the complexities of the different approaches, this report separates the data on hazards into three categories: illness data, exposure data, and hazard identification data. *Illness data* document the adverse health effects on students of exposure to an agent in the school environment. This information is the most certain of linking exposure to the agent to the illness. *Exposure data* indicate that exposures have occurred, may have occurred, or, because of the hazard's presence, may occur in schools. *Hazard identification data* come from animal or human studies, quite apart from any school exposure information, and demonstrate that exposure to an agent can lead to an adverse effect. This information is the least certain in linking exposure to illness.

A few basic toxicological principles are discussed in chapter 2. For most of this chapter, the data are discussed in terms of the nature of exposure and the possible effects. Toxicologists categorize exposure to chemicals as being acute, chronic, or a variation in between, i.e., subacute or subchronic (99). For most situations, acute exposures are high-level exposures for less than 24 hours, usually from a single exposure incident. In contrast, chronic exposures are repeated exposures occurring over a long time period at exposure levels below which acute effects are usually visible. Often the health effects arising from a single, acute high-level exposure differ from those experienced at chronic, low-level exposures.

In addition to illness, this chapter examines the data on fatalities arising from illnesses. To do so, OTA used the national mortality data compiled from state death certificates by the National Center for Health Statistics (NCHS) in the Department of Health and Human Services on an ongoing basis. National mortality statistics include information on the cause of death and the demographics of the decedent. These data are available on the natural causes of death for school-aged children, using the available age groupings of 5-9, 10-14, and 15-19 years old. Natural causes of death refer to causes such as illness, disease, or chronic conditions as opposed to external causes, although poisoning is considered a cause of illness as well.

MATERIALS IN THE SCHOOL ENVIRONMENT

Materials used in the school curriculum and in the maintenance of the school facilities present possible health threats to students. These materials are usually found in any home. They differ from most hazards discussed in this chapter, however, because they are intentionally brought to the school grounds for use in teaching, cleaning, repairing, painting, and otherwise maintaining school facilities. This section will cover possible poisoning as well as exposure to and the health implications of specific materials of most concern—namely, lead and pesticides. The section will end with a discussion of other school materials with possible toxic properties, but for which OTA found very little in-school exposure and illness data.

The agents discussed here can enter the body through skin contact or ingestion; in contrast, indoor air pollutants, covered in the next section, enter through inhalation. Those agents coming into direct skin contact can directly damage the skin, cause skin allergies, or be absorbed through the skin into the body. Some chemicals, like acids, can burn or damage the skin; others, like paint thinner, can directly irritate; and some, like formaldehyde, can trigger an immune reaction, producing a skin allergy, such as a rash. Some agents are ingested. Often ingestion results from inadvertent contamination of food or drinks, but it can also be deliberate, such as with young children.

Poisoning

Chemicals that are toxic at very low levels are considered poisons. Exposures to them are often reported to regional poison control centers, and those reports are subsequently collected into a database by the American Association of Poison Control Centers (AAPCC), the professional organization for regional poison centers. The AAPCC Toxic Exposure Surveillance System (TESS) reported more than 1.86 million and 1.75 million human exposures in 1992 and 1993, respectively (114,115). Although this exposure information cannot be used as evidence of actual poisoning—reported health effects were not medically confirmed—the exposures were of sufficient concern to medical personnel and to the patient, his or her family, friends, or associates to warrant a call to the center. Because such reporting is voluntary, not every poisoning is reported to the regional poison control center.

According to the TESS, about 15 percent of all reported exposures to poison were to school-aged children. (Over half were to children under 5.) Schools accounted for only 1 percent of all reported poisoning exposures in 1992 (114) and 1.2 percent in 1993 (115) (see table 4-2). However, in-school exposures include all exposures, to staff as well as students, and all schools,

TABLE 4-2: Total Poison Exposure Cases, 1988, 1992 and 1993

Site	1988 Data (%)[a]	1992 Data (%)[b]	1993 Data (%)[c]
Residence	80.3	92.1	90.3
Workplace		2.5	2.8
Health care facility		0.6	0.5
School	4.6	1.0	1.2
Other	15.1	2.1	2.8
Unknown		1.7	2.3

[a] Scheidt, et al., "The Epidemiology of Nonfatal Injuries among US Children and Youth," *American Journal of Public Health* 85:932-938.
[b] Litovitz, et al., "1992 Annual Report of the American Association of Poison Control Centers Toxic Exposure Surveillance System," *American Journal of Emergency Medicine* 11(5):494–555, 1993.
[c] Litovitz, et al., "1993 Annual Report of the American Association of Poison Control Centers Toxic Exposure Surveillance System," *American Journal of Emergency Medicine* 12(5):546-585, 1994.

including preschools and universities. Because the data do not report the ages of exposed persons with the location of exposure, the percentages of school-aged children exposed in-school cannot be accurately determined. But at most, 7 to 8 percent of exposures to poison among school-aged children occurred in schools during 1992 and 1993.

In accordance with that estimate, the Child Health Supplement of the 1988 National Health Interview Survey (NHIS) determined that about 5 percent of poisonings occur in school, compared to 80 percent at home (199). Poisoning represents less than 1 percent of all injuries in school. The survey included questions on the circumstances, causes, and impact of all medically attended nonfatal injuries for a representative sample of U.S. children and adolescents. Those data, however, include children 5 years old and younger, which—according to the AAPCC data (114,115)—accounts for about 60 percent of all human exposure cases. In addition the data are from 1988 whereas the AAPCC data are from 1992 and 1993.

The AAPCC data reported only possible poison exposures and not the resulting health effects. The National Center for Health Statistics (NCHS) examines hospital discharge records and conducts household surveys to assess impacts. The NCHS data cover poisoning from drugs and other chemical substances. NCHS estimated that nearly 47,000 school-aged children were hospitalized and 191 died as a result of poisoning. For children ages 5–9, an estimated 3,000 children were discharged in 1993, at a rate of 1.5 per 10,000; for children 10–14, it was 9,000 children at a rate of 4.9/10,000; and 15- to 19-year-olds had 35,000 children discharged at a rate of 20.5 per 10,000. A serious problem with hospital data is the lack of complete information on the causes of injury and poisoning. Accurate and reliable information regarding the external causes of injury (E-codes) is critical, yet a CDC study found that only 44 percent of injury and poisoning patients had listed one or more E-codes (75). Some of these poisonings resulted from deliberate or accidental ingestion of large doses of medication. Because of the limited records, a paucity of data existed for estimating the hospitalization of school-age children from unintentional exposure to toxic materials—the issue of concern in this section. These estimates also reflect total discharges from hospitals and not necessarily different students.

The rest of this chapter discusses the sources of exposures to specific agents possibly contributing to illness. School officials and public health professionals have identified many of these agents as posing possible health risks to students in school. Others are perceived by the public as hazards. Considerable evidence demonstrates that exposure to lead and specific pesticides can result in adverse health effects to this age population. Less information is available, however, concerning exposure to toxic supplies and materials used in arts, industrial arts, and science courses. Few studies exist on which to associate illnesses with in-school exposures to these agents.

Lead

Lead is recognized by many public health authorities as the foremost environmental health hazard to children (238). According to government estimates, about 2.4 million preschool children have lead poisoning at blood levels of 15 micrograms per deciliter (µg/dL) or higher (237). This figure represents 17 percent of all preschool children in the United States. In the inner city, more than 50 percent of minority children suffer lead poisoning. Levels previously considered safe have been found in numerous studies to produce adverse effects on children's intelligence and behavior. This newer body of research prompted the Centers for Disease Control and Prevention (CDC) in 1991 to reduce the target level for public health intervention and recommend that all children have their blood screened. The blood level signifying lead toxicity, formerly 25 µg/dL, has been lowered to 10 µg/dL (238). Environmental exposures once viewed by public health officials as unimportant are now taken more seriously. Similarly, certain public interest organizations focus on low-level lead exposure to children (133).

Young children up to age 6 or 7 are most vulnerable to lead toxicity because they intake, absorb, and retain lead to a greater degree than older children or adults. Behavioral differences, such as greater hand-to-mouth activity, and nutritional and physiological differences, such as iron deficiency and higher metabolic rates, are responsible for young children's enhanced vulnerability (151). Most importantly, young children are more susceptible to lead's effects because exposure interferes with, and may permanently disrupt, neurological development (40). The early effects of lead on intelligence and behavior can persist into adulthood (157).

The overall contribution of lead hazards in schools to the problem of childhood lead poisoning is unknown (224). Neither lead hazards[2] in schools nor their health effects have been comprehensively and systematically evaluated across the country. Yet any school built before 1980[3] can contain potential lead hazards if its paint is peeling, deteriorating, or subject to abrasion. Lead in drinking water can be found in any school regardless of when it was built because many different points in the delivery system may still contain lead. Although some small-scale studies of school exposures, mostly from drinking water, have been conducted and are described later in this section, researchers have focused on the residential setting because it is where infants and preschoolers, who are at greatest risk for lead toxicity, spend most of their lives. Blood lead levels are most closely linked to young children's residential paint levels (15,28). The higher the concentration of lead in house paint and dust, the greater is the child's blood lead level. The highest blood lead levels are found among children residing in dilapidated pre-World War II housing.

Some question the need to study the preschool and school environment in light of the strong influence of residential lead and the early age at exposure. Yet, if lead hazards are present, both the preschool and the school environment may be important sources of exposure for four reasons:

- These are settings in which children spend significant amounts of time and an opportunity for exposure exists. Exposure to lead is cumulative; the overall body burden is stored in bone and teeth and can be remobilized later during pregnancy and aging;
- Lead levels in school-aged children, not just those of earlier ages, are important: higher average lifetime lead levels upon school entry at age 6 are associated with lower IQs (8,43);
- Primary and secondary schools host programs such as Head Start and other types of child care or educational programs that bring infants and young children into the school environment for extended periods, and;
- Children of any age can become poisoned given a high enough exposure and a viable route of exposure such as inhalation or ingestion.

What follows is a summary of the health effects of lead, a description of the opportunities for such exposure in schools and child care centers, a compilation of regulations pertaining to schools, an evaluation of studies in schools and child care centers, and an overall assessment of the risk children face in these settings. In a departure from other topics in this report, this section focuses on child care centers as well as schools because of the vulnerability of preschool age children to the deleterious effects of lead.

Health Effects

Lead affects almost every bodily system. As the dose increases, it exerts increasingly serious health effects, and no threshold has been identified below which exposure is safe. At high doses (>70 μg/dL), which are now rare, lead can cause coma, convulsions, and death. At less severe dose levels, it can cause damage to the kidney, the hematopoietic system, and vitamin D metabolism. At lower doses in children (>10 μg/dL), lead can impair intelligence, neurobehavioral development, growth, and hearing (151,155,237). The impacts of low-level lead exposures have been the focus of much recent research. Many studies have found these exposures to reduce mean IQ scores between 4 and 6 points (151). When these and other studies were combined and analyzed as part of a meta-analysis, strong support emerged for the inverse relationship between children's IQ scores and lead burden (156). While the impact on IQ may seem almost inconsequential on an individual

[2] Lead hazards are generally considered to include: chipping or peeling lead-based paint; lead-based paint on friction, impact, or chewable surfaces; and excessive levels of lead in dust, soil, or drinking water.

[3] In 1978 the manufacture of lead-based paint was banned almost entirely for most uses.

level, it can have a profound effect on society: OTA (228) calculated that a 5 percent reduction in mean IQ scores in a population of 100 million can prevent 1.3 million people from reaching superior intellectual performance, as measured by an IQ of 130 or higher.

Some of the first medical articles about childhood lead poisoning appeared in the *Australian Medical Gazette* at the turn of the century. In 1904, A.J. Turner and J.L. Gibson traced childhood lead poisoning to the ingestion of paint chips from painted porch rails (155). The strength of this early research was sufficient to warrant the banning of lead-based paint in Australia by 1920, an action that was not taken in the United States until 1978. Years of research have established that most children become lead poisoned from paint as a result of inhalation and ingestion of lead-contaminated ***dust***. When lead-based paint deteriorates and flakes off, the paint chips eventually disintegrate to a layer of lead-contaminated dust that settles on interior and exterior surfaces. There are many other sources of lead exposure, which are discussed in the next section, but lead-based paint and lead-contaminated dust are responsible for most cases of lead poisoning in the United States (151,238).

Exposure in Schools and Child Care Centers

Schools and child care centers present many opportunities for exposure to lead. In these settings, it is important to distinguish between the sources and the routes of exposure (table 4-3). The most common sources of lead exposure are: deteriorating lead-based paint, lead-lined water coolers, water fixtures, lead pipes, and lead-containing art supplies such as pottery glazes[4] and silk screen inks. Leaded gasoline is another less obvious—but no less important—source of exposure at school. Even though leaded gasoline was quickly phased out as a result of 1978 regulations under the Clean Air Act of 1970, decades of past use have resulted in the deposition of 4 to 5 metric tons of lead in the environment (246). Since lead is an element, it does not decay or disintegrate: atmospheric lead settles onto the upper 2 to 5 centimeters of soil, and children can inhale or ingest it at school playgrounds where the soil is exposed.

Lead from all of these sources gains access to the body through one or more of the following routes: dust, soil, air, and drinking water. Dust (interior or exterior) is the major pathway of exposure to lead-based paint. Leaded paint dust can also settle on soil, another pathway of exposure. Drinking water at schools can be contaminated with lead from water coolers with lead-soldered or lead-lined tanks or from plumbing fixtures. Lead leaches from tanks into the water, especially after the long periods of inactivity that are characteristic of schools. Lead can accumulate at high concentrations overnight, on weekends, and over school holidays. This was one of the many reasons Congress passed the Lead Contamination Control Act of 1988, which banned the sale of water coolers that were not lead free and required manufacturers to repair, replace, or recall existing lead-containing water coolers.

The environment surrounding a school can also influence lead exposure. Higher concentrations of lead in soil are found closest to major thoroughfares, reflecting past deposition of leaded gasoline emissions into the air (246).

TABLE 4-3: School Exposure to Lead

Sources	Pathways	Routes of Entry
Paint	dust, soil	inhalation, ingestion
Water coolers, pipes, plumbing fixtures	water	ingestion
Leaded gasoline	soil, dust	inhalation, ingestion
Art supplies	dust, air	inhalation, ingestion

SOURCE: Office of Technology Assessment, 1995.

[4] Even though many lead-free glazes are available, lead-containing glazes (up to 40 percent lead by weight) are still found in elementary schools. Even with lead-free glazes, lead vapors can be released from kilns previously used to heat lead-containing glazes (129).

School playgrounds in the inner city or near major highways are likely to be most affected. Improper sandblasting or abatement of lead-based paint on bridges and water towers can spread leaded debris throughout the nearby community (102,177). Exterior paint applied to steel structures can contain as much as 90 percent lead by weight. Finally, lead exposure is possible if a school is located near a smelter where lead ores are refined or near a plant that manufactures batteries (208,266). Significantly elevated levels of lead were found in the surface enamel of the permanent teeth of children from a school close to a nonferrous metal plant in Belgium (30).

All exposure to lead is cumulative. While it is difficult to rank sources in terms of their contribution to the overall problem of childhood lead poisoning, lead-based paint is considered of premier importance, followed by leaded gasoline fallout into dust and soil, and then by lead in drinking water (151).

Regulations Pertaining to Schools

There are no comprehensive federal laws governing exposure to lead in schools. Yet schools are indirectly affected by many existing federal regulations covering drinking water, paint, construction and renovation, and art supplies, described below. Some states and localities have additional laws and regulations that are not discussed in this report. The regulations and standards reviewed provide a sense of the magnitude of exposure necessary for federal concern to measure against the lead levels observed in certain schools.

Drinking Water

In 1991, the Environmental Protection Agency (EPA) established an action level of 15 parts per billion (ppb) for public water systems (252). When more than 10 percent of the samples drawn exceed this action level, public water systems must take steps to reduce lead levels through corrosion control and public education. Schools are not required to meet this action level, because EPA regulates only public water systems and not end users such as schools or residences. Instead, schools are **encouraged, but not required,** under the 1988 Lead Contamination Control Act (P.L. 100-573) to test their drinking water and meet a recommended lead level of 20 ppb.[5] However, funds authorized under this legislation to help defray costs of testing were never appropriated. The 1988 legislation also banned the manufacture of lead-containing water coolers and required EPA to compile and distribute to the states a list of the brands and models of drinking water coolers identified as not being lead free. Plumbing fixtures containing up to 8 percent lead are still permitted under the legislation, however.

Paint

The only federal legislation pertaining to paint concerns its manufacture. In 1978 the Consumer Product Safety Commission (CPSC) prohibited the use of paint containing more than 0.06 percent lead by weight on interior and exterior residential surfaces, toys, and furniture, but not for industrial or military purposes. Intact paint on surfaces painted before 1978 does not represent a lead hazard until it begins to deteriorate into fine particles of dust through normal weathering or abrasion. Currently, there are no federal standards for lead in dust or soil, two major routes of exposure for children. Under the 1992 Residential Lead-Based Paint Hazard Reduction Act,[6] EPA was required to define "lead-contaminated dust" and "lead-contaminated soil" within a specified time period, but it has failed to meet the deadline. Once standards have been developed, there are no associated enforcement measures for exceeded levels.

Construction and Renovation

Renovation of schools built before 1980 can contaminate the school environment with dust from

[5] This level can actually be more stringent than the 15-ppb action level because the methods recommended to obtain a sample prevent dilution of the lead and yield a more concentrated sample (143).

[6] This legislation, P.L. 102-550, is commonly known as Title X.

lead-based paint. While there is no legislation directed at school renovations per se, the 1992 Residential Lead-based Paint Hazard Reduction Act mandates more stringent worker protection and this has an impact on reducing lead contamination during all renovations, including those done in schools. Renovation of older structures containing lead-based paint can liberate excessive amounts of lead-contaminated dust that settle in the interior environment and on the outdoor soil. Even though children can be shielded from dust or physically removed from the environment during renovation, lead contamination can persist long after renovation is completed because lead settles nearby, where it is retained in undisturbed soil.

Art Supplies

The Labeling of Hazardous Art Materials Act of 1988 requires that art materials containing chronic health hazards be labeled. It also requires the materials to carry a statement that they are inappropriate for use by children and authorizes the CPSC to obtain a court injunction against schools that purchase chronically hazardous art materials for children in grades 6 and below. Since neurotoxins are included in the definition of chronic hazard, lead-containing products are subsumed under this legislation. However, concern remains over imported art supplies, since importers are often unfamiliar with the contents of the materials being imported (129).

Studies in Schools and Child Care Centers

Across the United States in 1990, there were more than 110,000 schools enrolling an estimated 45.4 million children and more than 235,000 state-regulated child care facilities with an enrollment capacity of 4.5 million (224). Millions of other children are placed in unlicensed day care settings.

OTA was not able to identify any studies that examined the contribution of lead in preschools or schools to adverse health effects in children. The only studies uncovered, described below, are those monitoring drinking water or paint lead levels in some facilities in selected areas of the United States. These studies do not systematically and comprehensively assess the presence of lead in preschools and schools nationwide, in contrast to the data available for U.S. housing.[7] Nor do they examine lead levels in all media combined—paint, drinking water, and soil. They focus primarily on drinking water, despite the fact that this source is not the greatest contributor to the problem of childhood lead poisoning. Finally, the preschool environment, where children are at greater risk because of their age, has been studied far less than the school environment. These conclusions were also reached by the General Accounting Office (224), which determined that the extent of lead hazards in child care and school facilities is unknown.

GAO contacted child care licensing agencies in 16 populous states and 57 school districts within 10 states. It sought to determine whether these state and local agencies collected data on lead hazards in preschools and schools. With respect to child care facilities, GAO found that none of the relevant state agencies routinely inspected all regulated facilities for lead hazards in paint, drinking water, and soil. Only two of the 16 states required routine lead paint inspections. Seven others have limited testing for lead paint hazards. Eight of the 16 states tested some facilities for lead in drinking water. One state required some soil inspections.

Since schools are regulated at the local level, GAO contacted the school districts directly to determine their requirements for testing lead hazards and the availability of testing data. GAO identified 50 of the 57 school districts as conducting some testing for lead hazards in drinking water, but only nine districts tested paint and only three tested soil. The GAO study did not report the results of the school district's actual

[7] Based on a nationally representative sample, a comprehensive study of lead-based paint in privately owned housing in the United States was conducted by the U.S. Department of Housing and Urban Development and reported to Congress in the "Comprehensive and Workable Plan for the Abatement of Lead-Based Paint in Privately Owned Housing," January 1991.

lead readings, nor was it clear whether the districts compiled this type of data. Most districts appear to have reported on the percentage of schools in which lead hazards were found, not the extent of the hazard.

Other studies that address lead exposure in preschools or schools are generally of two types, depending on how the data were acquired: *primary* and *secondary* studies. In primary studies, authors collect and analyze their own data; in secondary studies, authors analyze data collected by others.

Primary Data Collection Efforts

New Jersey Department of Environmental Protection and Energy. Two studies of lead in drinking water were published in the early 1990s by the New Jersey Department of Environmental Protection and Energy (DEPE). In the first study, DEPE collected and analyzed lead samples. The second study is a survey of school district and day care efforts in the state, described in the following section.

Schools that are aware of excess lead in their drinking water are encouraged to flush water fountains for 10 minutes each morning in order to reduce lead levels. A researcher with DEPE sought to determine whether this practice was effective. Her findings were the only ones from among the school studies described in this section that were published in a peer-reviewed professional journal.

In this study of 50 schools, Murphy (142) compared lead levels in water samples taken at three separate times: first-draw samples, samples taken after the 10-minute flushing procedure, and samples taken immediately before lunch time. As expected, the highest levels were found in the first-draw samples. The 10-minute flushing was found to reduce lead concentrations from a median of 10 to 5 ppb—both of which are lower than the EPA action level (15 ppb) and the recommended school level (20 ppb). One limitation of this study is that it is too small to be considered a representative sample of New Jersey schools, but the participating schools were selected to represent a spectrum of public and private schools constructed over a broad time span.

South Carolina Day Care Facilities. Legislation passed in South Carolina in 1986 required lead testing of day care facilities and foster homes as a condition of licensure. If a lead hazard is present, it must be removed, replaced, or permanently covered within 30 days. Facilities are licensed for two years, after which they are relicensed. Lead inspection generally does not occur on the relicensure. Inspection also occurs upon the identification of a child who has an elevated blood lead level. Under the state's related environmental regulations, lead inspections are designed to identify paint lead hazards on exposed surfaces that are chewable or readily accessible to children 6 years of age or younger, such as windows, railings, and any peeling or chipping paint surfaces. A concentration in excess of 0.06 percent lead by weight is defined as hazardous. Recently the state established a policy of inspecting soil as a routine component of lead inspection. In the absence of an EPA soil standard, the state deems lead a hazard when soil concentrations exceed 200 parts per million (35).

According to the FY 1993 figures from the state, 13 percent of the day care centers and foster homes inspected contained a lead hazard. From FY 1988 to FY 1993, there were lead hazards in 17 percent of the inspected facilities. Although the percentage of facilities found to have lead hazards may seem high, it should be pointed out that the lead hazard level employed by the state, 0.06 percent lead by weight in paint, is more stringent than the new federal threshold of 0.5 percent established under the 1992 Residential Lead-Based Paint Hazard Reduction Act.

The state data discussed were not contained in a formal report; rather, they were compiled by the Department of Health and Environmental Control on a sheet that lists summary data without any methodological or supporting information. Therefore, it is difficult to assess the quality of the data, including the conditions under which measurements were taken. Many questions remain. Since the data are not broken down by location or facility type, it is not known what percentage of hazards is found at day care centers or foster homes. Further, no information is reported about the mean concentrations and overall distribution found statewide, the number of samples and sample types (soil versus paint) taken at each facility, and how many samples exceeding the statutory level of 0.06 percent lead by weight would constitute a "lead hazard" determination at a facility.

Secondary Surveys of State and Local Efforts

Natural Resources Defense Council. After passage of the 1988 Lead Contamination Control Act, the Natural Resources Defense Council (NRDC) sought to determine if this legislation had succeeded in encouraging schools to test for lead in drinking water. Based on survey results from 50 states and three territories, NRDC found very little testing taking place (127). Thirty-two states had no information on preschool testing, and only 17 reported any sampling of day care or preschool facilities. A total of 1,650 such facilities had been sampled, 0.6 percent of all licensed child care facilities in the United States.

Testing of school drinking water was found to be more common. School drinking water was sampled and analyzed by 47 states, but only four states sampled virtually all of their schools. The majority of states (27) sampled 25 to 82 percent, and 16 states sampled 25 percent of their schools or less. Only six of the 47 states provided actual numerical lead levels to NRDC, yet the methods used to collect samples were so disparate that NRDC was unable to analyze the data collectively. Some readings ranged from 100 to 12,000 ppb.

New York City School Scorecard Report. The New York City Board of Education monitors the physical appearance of all school buildings on an ongoing basis and presents its findings in the annual School Scorecard Report. The significance of this report is that its findings are used to trigger a lead paint abatement strategy developed by the New York City Chancellor's Task Force on Lead Hazard Reduction.[8]

The School Scorecard Report covers more than 45,000 classrooms examined twice a year by inspectors. Two of the five categories monitored by inspectors concern the condition of the paint on the walls and on the ceilings. **No attempt is made to measure the lead content of paint in the classrooms;** rather, visual inspection is used as a management tool for triggering building maintenance and repairs. A visual inspection focusing on peeling and chipping paint can be an important means of identifying lead hazards, especially in buildings constructed before 1980. Almost all New York City schools were built before 1980.

Inspectors rate the conditions using a 7-point scale, with 0 referring to "no damage" and 6 to "extreme damage." In 1991-92, the most recent year for which data are available, more than 6,000 classrooms had damaged walls and over 7,000 had damaged ceilings rated 2 or higher—the ratings considered to present a lead hazard (160). The actual number of classrooms affected is not clear, but presumably many of the damaged walls and ceilings are in the same classrooms. It is also not clear whether inspectors are consistent in their own ratings (intra-rater reliability) and whether there is consistency across inspectors (inter-rater reliability). This is one reason for the need to verify the ratings with objective laboratory measurements. According to recommendations of New York City Chancellor's Task Force on Lead Hazard Reduction, a full-scale abatement should be undertaken when a scorecard rating of 2 or higher has been amplified by a full-scale assessment of the lead hazards using actual paint lead measurements.

[8] Concerns about lead paint contamination in school classrooms prompted the creation of a special advisory committee to the New York City Chancellor, the Chancellor's Task Force on Lead Hazard Reduction (161). Its final report contains recommendations for reducing exposure to lead paint. Since this report represents a practical abatement strategy rather than a study of exposure or health effects, it is not discussed here.

Office of the Comptroller of the City of New York. In July 1993, the New York City Comptroller released a report on lead in drinking water at day care centers and schools.[9] The report was amplified by some testing directly by the Office of the Comptroller, but most of the data were from tests conducted by a variety of city agencies that oversee schools and day care centers. The report found that more than half of the city's 820 elementary and intermediate schools, serving 350,000 children, had not been tested for lead in drinking water. Of the 264 schools that had, 14 percent had lead levels exceeding 15 ppb, the EPA action level. Later testing directly by the Comptroller's Office revealed that the lead content had been reduced at most of the schools with excessive levels (27). In December 1993 the New York City Chancellor announced a new plan for testing water in all city schools.

Testing was even less prevalent at day care centers. Of the 688 city-funded day care centers serving more than 40,000 preschool-aged children, 78 percent had not been tested for lead in drinking water by the appropriate city agency, the Human Resources Administration. This agency tested 151 day care centers and found that 30 percent exceeded the 15-ppb lead level. In addition, the Comptroller's Office conducted its own testing of 50 centers randomly selected from the 688. It found that 18 percent had lead levels exceeding 15 ppb, but actual measurements are not reported.

New Jersey Department of Environmental Protection and Energy (DEPE). Between 1990 and 1991, DEPE mailed a survey to all school districts and licensed day care centers throughout the state seeking information about previously conducted water testing (143). By asking the school additional questions about its water supply and the year of school construction, DEPE was able to analyze the school data according to the year of construction and other parameters. Only 271 (8 percent) of the state's 3,218 schools responded to the survey, 47 percent of which reported sampling for lead in drinking water. Of these 271 schools, 20 percent of their first-draw morning samples exceeded a 20-ppb lead level. Schools constructed between 1950 and 1987 had the greatest percentage of first-draw and flushed samples exceeding 20 ppb. Yet excessive lead levels were also found in first-draw samples in schools constructed between 1988 and 1992, which the authors attributed to lead-containing fountain and faucet fixtures. The authors concluded that water sampled in New Jersey schools built before 1950 had lower lead levels than water sampled in newer schools.

With respect to day care centers, testing had been done by only 2 percent of the 485 centers that responded to the survey. The results ranged from below detection to 20 ppb, but given the paucity of sample data, the authors were unable to perform any further analysis.

Assessment of Risks

It is impossible to assess quantitatively the risks from lead exposure to our nation's 46.4 million school children and 4.5 million preschoolers. No comprehensive studies of school-based lead exposures or their potential adverse health effects have been undertaken. Most schools and preschools do not test for lead. When they do test, lead may be found almost anywhere—in dust, soil, and/or drinking water. The amount of lead varies according to many factors, such as year of construction and condition of the paint; types of plumbing fixtures and water delivery systems; and proximity of the school to highways and other places where lead contamination, past or present, has occurred. Older school settings in poor condition are more likely to present the greatest risks to children because of deteriorating lead-based paint, which is regarded as the most important source of childhood lead poisoning. However, the mere presence of lead in the environment does not ensure entry into a child's body. The age of the child is a critical factor. Preschool children are more vulnerable to the health

[9] The data contained in this report were not included in the GAO study (224).

effects of lead exposure, especially due to their hand-to-mouth behavior, which heightens the entry of lead into the body. Older children display less hand-to-mouth behavior but, like preschoolers, can ingest lead from drinking water. Lead can be found in drinking water regardless of the year of construction of the facility and, according to one study, is more likely to be found in schools built after 1950. Lead exposure from all sources, whether in the home or the school environment, is cumulative.

Once absorbed into the child's body, lead can exert adverse effects that vary according to dose and age at exposure. Even low levels of lead exposure during preschool years can result in reduced IQs. While school-aged children may not be as susceptible as preschoolers to low-level exposures, higher exposures at any age can result in lead poisoning. **Given the limited extent of environmental monitoring of preschools and schools where lead is likely to be present, the risks from all sources of lead warrant further evaluation. Yet no data demonstrate that the level at which students are currently exposed to lead—if at all—in classroom or school facilities is greater than that for out-of-school exposures.** The evidence suggests that the largest risks to children from lead exposure are paint chips from residential dwellings. However, since the effects of lead are cumulative, in-school exposures may contribute with other exposures to produce deleterious blood lead levels.

Pesticides

Pesticides are agents used to kill or control pest populations of all types. They are employed in agriculture to enhance agricultural productivity by reducing the loss of food crops to insects and other pests and to control growth of weeds and other non-food plants. Many developing countries rely on them to disrupt the transmission of disease by certain disease vectors; malaria, for example, is transmitted by mosquitoes and other blood-carrying insects. Pesticides have a lesser role in urban pest control: rodent control, weed control on highways and utility rights of way, residential dwellings, office buildings, and schools (178). Approximately one-quarter of the 1.3 billion pounds of pesticides used in this country is for non-agricultural purposes, including soaps and disinfectants (228).

Pesticides can serve important functions in schools. Racke (178) categorized urban pests as indoor nuisance, outdoor nuisance, turf and ornamental plants, home garden, and structural, all of which apply to schools depending on local and regional conditions and pest populations. The nature of the urban pest dictates pesticide use patterns. Indoor nuisance pests—cockroaches, ants, mice, mold, and mildew—can arise in school from improperly stored food in the cafeteria or in students lockers and areas of continued dampness, such as locker rooms. Outdoor nuisance pests—mosquitoes, ticks, rats, and poison ivy—can be found in lawns, athletic facilities, and playgrounds. Turf and ornamental plant pests and home garden pests include aphids, crabgrass, moles, slugs, and snails, which can be found in school lawns and gardens and on athletic fields. Finally, structural pests include termites and fungi found within building materials.

Even though they share the common feature of killing or controlling pests, pesticides represent a very large and extremely diverse array of biological, chemical, and physical agents. More than 3,000 chemicals and 50,000 products are registered under the Federal Insecticide, Fungicide, and Rodenticide Act, a listing that consists of 880 active pesticidal ingredients and 2,200 inert ingredients (228).

Despite their many uses and benefits, pesticides can also pose public health problems. Pesticides can be poisonous—even in low doses—depending on the toxicity of the specific agent (79,144). Possible pesticide poisoning generates a substantial number of calls each year to regional poison control centers to report pesticide exposure; there were more than 77,000 such calls in 1992 (114).

These toxic effects and a concern that pesticides may be more toxic to children than adults for certain effects (152) have prompted some school boards, parents, and others to attempt to reduce, if not eliminate altogether, the use of pesticides in the school environment (181,182,218). To do so, schools around the nation are implementing integrated pest management programs (248) (see box 4-1).

Regulations

Congress passed the Federal Environmental Pesticide Control Act (FEPCA) of 1972, which provides the basic statutory authority for current pesticide policy. FEPCA, by amending the Federal Insecticide Fungicide and Rodenticide Act (FIFRA) of 1947, shifted the focus of pesticide registration from a question of product efficacy to questions of health and safety of humans and the environment, and shifted regulatory authority from the U.S. Department of Agriculture to the U.S. Environmental Protection Agency. Amendments in 1972, 1978, 1980, and 1988 required EPA to regulate pesticide use to prevent "unreasonable adverse health effects," but they require a balancing of risks and benefits to determine whether a pesticide should be allowed on the market or have its registration canceled.

Because many pesticides were registered on the basis of toxicity data that might now be considered inadequate, Congress has requested EPA to reexamine the safety of registered pesticides. EPA does not require the submission of new applications, but it reviews the available data for adequacy and requires updated health effects data. The 1988 amendments to FIFRA requires EPA to review 600 active pesticide ingredients of existing pesticides by 1997. Results of a GAO report (225) suggest that EPA is having difficulty in at least one area—re-registering lawn care pesticides, which rid lawns of weeds and pests—and the review may not be completed until 2007.

Under current law, states may set up more stringent requirements for pesticide use than those provided in federal statutes. Several states, notably California, Texas, and Washington, have initiated their own worker and public programs. Nine states have laws requiring reporting pesticide illness or pesticide use, although most are unenforced (228). Notable exceptions are the California and Washington systems, which require reporting of pesticide illness; both are in place and working. California has an extensive and well-funded pesticide regulatory program that exceeds EPA standards in addressing local conditions and patterns of use (67). California enacted the Birth Defects Prevention Act of 1984 to require adequate health effects data on all pesticides, with data on the 200 pesticides that are most widely used statewide and that are suspected to promote birth defects having shorter time frames and tighter restrictions. This law prohibits the conditional registration of any new pesticide without complete and valid data on health effects. It also requires the cancellation of any pesticide containing an active ingredient that causes significant adverse health effects that cannot be mitigated. However, EPA has yet to review high-priority active ingredients in the older pesticides or inert ingredients, which often comprise the bulk of the pesticide product. These ingredients can be such toxic substances as xylene, toluene, and benzene (228).

Exposures and Illness

There are at least four different ways students can be acutely exposed to toxic levels of pesticides in the school environment. First, pesticides can drift from nearby agricultural areas to school grounds or onto students located outside the building. Second, pesticides can be used inappropriately in a room where students work or play, or the agent might be stored incorrectly (e.g., in containers from which students may accidentally drink) or in unsecured containers so that students come in contact with them. Third, insufficient warning or ventilation can result in students' reentering an area where pesticides have recently been applied and the residual levels of pesticide in the air or on surfaces are too high. Finally, accidents can result in spills and exposures.

A poorly understood area of pesticide exposure is that of routes of chronic exposure. Schools, like residences, are repositories for pesticides that are either applied indoors or transported indoors. Pesticides may accumulate from repeated use, be brought in from outdoors on shoes and clothing, or enter by air intrusion.

BOX 4-1: Integrated Pest Management in Schools

Rather than using conventional pesticides to kill pests after they have become a problem, integrated pest management (IPM) approaches the pest problem from a different angle, emphasizing prevention and reduction of the source of the pest problems rather than trying to get rid of all of the pests at once. Comprehensive information regarding the lifecycles of the pests and their interactions with the environment, such as food and habitat, are used instead of relying solely on chemical-based pesticides to eradicate the problem. Preventative measures, such as education of janitorial staff and improved janitorial practices, landscaping, occupant education, and staff training, create inhospitable environments for the pests by removing basic needs like food, moisture, and shelter. This use of natural controls can minimize the use of pesticides, therefore reducing possible hazards to people, property, and the environment. The IPM programs do not completely eliminate the use of pesticides, but these measures can help to reduce the amounts used and the exposure to them.

Most school districts do not require that IPM programs be adopted. However, many school districts across the country, including Eugene, Oregon; Conroe, Texas; Dade County, Florida; Montgomery County, Maryland; Cleveland Heights, Ohio; and elsewhere, have voluntarily integrated IPM programs into their pest control management.

Evaluating the costs is almost always a concern when initiating a new program, such as an IPM program. IPM programs reduce pesticide use, thereby reducing possible health problems (potential liability) and costs (materials). Long-term reductions in the purchase of pesticides can offset the initial costs of one-time expenses, including structural and grounds modification. Labor costs, however, usually are higher for IPM programs than they are for conventional pest control programs.

Setting up an effective IPM will take time, money, and the support of all of the participants, which includes faculty, students, and staff. These IPM programs are proving to be a viable alternative to conventional pesticide programs. Some big city examples exist in the California cities of Los Angeles and San Diego.

SOURCES: Dade County Public Schools, Department of Safety, Environment and Hazards Management, *Integrated Pest Management Procedures*, Sept. 12, 1994; Northwest Coalition for Alternatives to Pesticides, "A Better Way: Integrated Pest Management (IPM)," *Getting Pesticides Out of Schools*, 8–13; U.S. Environmental Protection Agency, *Pest Control in the School Environment: Adopting Integrated Pest Management*, EPA 735-F-93-012, August 1993.

Once inside, they may become associated with dust and accumulate in carpets, upholstered furniture, draperies, and on other surfaces. Protected from degradation by sunlight, rain, temperature extremes, soil microbes, and wind dispersion once transported indoors, pollutants may persist for years (112). Consequently, concentrations of pesticides indoors can be higher than those found in the air or soil immediately outside the building. Chronic exposure to these indoor residues, especially to young children, may be of some concern. It may be mitigated by better building design and management (110).

Any pesticide exposure database may suffer from underreporting. Because symptoms of poisoning are often described as "flu-like," patients, parents, school staff, and physicians may fail to associate an illness with pesticide exposure (109). On the other hand, it may be that in-school exposures are more likely to be reported than in-home, because of increased supervision by teachers and school staff knowledgeable about pesticide risks. In California, on-the-job exposures are more likely to be reported because of the workers' compensation system (67).

Case Studies and Reports

Beyond the American Association of Poison Control Centers database discussed earlier, no nationwide databases exist to report possible pesticide exposure in schools. Several public interest groups compile case reports on school poisonings and a few state programs exist. The available data from the case studies and reports vary in quality, with some being systematic studies and others citing newspaper accounts (see box 4-2).

Few studies or reports exist about exposures in schools and even fewer about levels of exposures. One study in an elementary school quantified reductions in insecticide exposure to school children from indoor air following delivery of an integrated pest management (IPM) training program to school staff responsible for in-school pesticide applications (121). The study found observable effects that were nonetheless below the no-observable-effect level[10] of insecticide, which were virtually eliminated with the implementation of indoor IPM techniques. Although a summary—not an analysis—of 67 selected cases in the California pesticide-illness reporting system for 1986, Maddy and Edmiston (122) nonetheless found three cases of in-school exposures that lead to a total of 44 students suffering from headaches, dizziness, and nausea. Three studies in the academic literature present the results of investigations into the role of pesticides in indoor air pollution (20,220,229). In two of the cases, problems arose when pesticides were applied in inadequately ventilated classrooms. An Australian study found that a school was contaminated by insecticides through poor work practices (20).

For the general population, the principle source of exposure to pesticides is the home (163). According to the results from the EPA's Nonoccupational Pesticides Exposure Study (NOPES), conducted in 1986-1988, 85 percent of the total daily exposure of adults to airborne pesticides was from breathing air inside the home (111), with the greatest number of pesticides and highest concentrations in one study in carpet dust (112). Another study examined the air concentrations and surface residues present 24 hours after indoor residential pesticide applications of Dursban, an insecticide for fleas, and found that even proper application can expose children entering treated rooms to potentially harmful doses of pesticides (52). These studies suggest to some that exposure of children to household pesticides may be high (107). Although there are no studies with direct comparisons, the greater amount of time spent at home and the results of the available studies indicate nonetheless that chronic residential exposures are larger, on average, than chronic pesticide exposure in schools (110).

BOX 4-2: Case Studies and Reports of Pesticide Exposure at School

New York

- Eastchester High School closed down for three weeks after students and staff complained of nausea, headaches, eye irritation, and respiratory problems. The day before, an exterminating company had applied the insecticides resmethrin, chlorpyrifos, and diazinon in the school.
- Chlordane, a termiticide, was found to be leaking from the foundation of a Yaphank, Long Island, elementary school in 1985 after the school received complaints of illness and water contamination problems. The New York State Department of Environmental Conservation banned the use of chlordane in 1985; the U.S. Environmental Protection Agency registration of chlordane nationally expired in 1988.

California

- Malathion, an insecticide applied to the exterior of classroom buildings in two schools, caused nine students and seven teachers' aides to experience symptoms of headaches, eye irritation, nausea, stomach pain, and dizziness. In all, 85 students and nine teachers were taken to a hospital emergency room for examinations and treatments.

(continued)

[10] The levels were below the no-observable-effect level (NOEL) for the insecticide (52). The NOEL is the highest dosage administered that does not produce toxic effects (99).

BOX 4-2: Case Studies and Reports of Pesticide Exposure at School (Cont'd.)

- Following application of the insecticides DDVP and chlorpyrifos for poison control, 29 students complained of headaches, sore throats, dizziness, and nausea.
- An application of chlorpyrifos led to 26 students seeking medical care with symptoms of headaches, nausea, dizziness, diarrhea, and vomiting. Ten others reportedly experienced symptoms, but did not receive medical care.

Idaho

- Eight children waiting for a school bus were reportedly exposed to a direct application of the insecticide malathion in a mosquito abatement district.
- An Idaho Falls mother complained of the smell of the herbicide 2,4-D and dicamba from an elementary school soccer field, onto which children were allowed 30 minutes after the application, in violation of the label directions.
- The superintendent of Castleford School District reported a strong odor of pesticides in a school after aerial application of the insecticide disyston onto a barley field near the school on a windy day.

Minnesota

- Four students and three adults were treated in a medical center following exposure to malathion used in a school greenhouse.

Midwest

- Teachers and the principal of a midwestern high school requested an investigation by the National Institute for Occupational Safety and Health (NIOSH). They complained of mucous membrane irritation, respiratory problems, tingling and numbness in the extremities, inability to concentrate, and thermal discomfort. The school had been recently treated for a termite infestation with the insecticides chlordane, chlorpyrifos, and diazinon. Air samples revealed the presence of these agents. NIOSH investigators concluded that the school's ventilation system was inadequate. After the school had been decontaminated and the ventilation system replaced, the symptoms abated.

Australia

- In 1986, a school in South Australia was treated for termites with aldrin, which was banned in the United States. School children complained of vomiting, diarrhea, lethargy, headaches, and irritability. Despite community fears that forced two investigations into the levels of aldrin found at school, investigators concluded that an association between levels and symptoms was difficult to make. They did find elevated blood levels of aldrin in some children.

Unidentified School Location

- Staff at a school for mentally handicapped children complained of headache, lightheadedness, dizziness, chills, nausea, shaking, weakness, and fainting after a pesticide bomb (with the insecticides dichlorvos and propoxur) was released for roaches. No children were exposed. The symptoms were consistent with pesticide toxicity, but no biochemical markers of exposure were detected.

SOURCES: I.C. Calder, E.J. Maynard, and L. Turczynowicz, "Aldrin Contamination at a School in South Australia," *Bulletin of Environmental Contamination and Toxicology* 51:185–192, 1993; Idaho Department of Agriculture Complaint/Investigation File Summaries, compiled July 1994 by the Northwest Coalition for Alternatives to Pesticides; G.O. Koppell, *Pesticides in Schools: Reducing the Risks* (Albany, NY: New York State Department of Law, 1993); K. Maddy and S. Edmiston, "Selected Incidents of Illnesses and Injuries Related to Exposure to Pesticides Reported by Physicians in California in 1986," *Veterinary and Human Toxicology* 30:246–253, 1988; *Saint Paul Pioneer Express*, Dec. 8, 1992, pg. 2B; D. Tharr "Indoor Environmental Quality in a School Building: Identification of a Problem and Mitigation," *Applied Occupational and Environmental Hygiene* 6:836–838, 1991; L. White, J. Clarkson, and S.N. Chang "Health Effects from Indoor Air Pollution: Case Studies," *Journal of Community Health* 12:147–155, 1987.

California Pesticide Illness Surveillance Program

The California Pesticide Illness Surveillance Program (CAPISP) is designed to make up for some of the deficiencies in the state's exposure-reporting system. From 1982 to 1991 (the last year for which data were available), the number of cases reported in schools, school staff, or students ranged from a low of two cases in 1983 to a high of 54 cases in 1987 (table 4-4). Student exposures represented about 1 percent of total nonagricultural exposures (8,600) reported to CAPISP from 1982 to 1991 (170).

The CAPISP is for physicians who have a reasonable cause to believe a patient is suffering from pesticide poisoning, or a disease or condition caused by a pesticide (67). This database contains no information on actual illness; it records case reports of reactions to incidental characteristics of the pesticide as well as those reflecting the primary toxic effect of pesticides. While some number of exposures result in illness, others do not. The database on which OTA's analysis was based only included those cases evaluated as definitely, probably, or possibly related to pesticide exposure, and excluded any unlikely cases caused purely by anxiety over the perceptions of poisoning. The proportion of unreported cases to total illnesses is unknown; because of differing interpretations of the CAPISP data, some argue that more in-school cases exist (182).

Most of these in-school exposures are to school staff, as shown by the number of students reporting exposure or illness in these cases. The exposed staff were often maintenance and custodial workers who are responsible for pesticide application but who frequently are not trained to do so. Some teachers reported prolonged exposure within a single classroom. For three years, no reported student exposures occurred, but 40 students reported being ill in 1987.

The majority of student exposures were single incidents, usually an accident, that affected many students. For instance, 19 students exposed in 1982 had mild rashes and eye irritation from a single incident in which sulfur drifted onto them at school; similarly, eight of 14 student cases in 1985 involved burning eyes resulting from a nearby spray of lime-sulfur, and five other students became ill when a school bus with 32 children was sprayed with several pesticides, including methamidophos (an organophosphate insecticide that affects the nervous system). In 1986, at least 17 (probably more) children developed a number of symptoms—sore throats, headaches, nausea, coughing, blurred vision, and burning eyes—when they came to school two days after school custodians applied dichlorvos (an organophosphate) in poorly ventilated areas. In 1987, the only reported incident of student exposure was an accidental release of chlorine gas, which sent 40 students seeking medical attention. Finally, the three cases reported in 1991 came after the nationally publicized spill of metamsodium (another organophosphate) into a stream in Dunsmuir, California, where a nearby high school was used as a medical triage center.

Pesticide Use Data

State agencies and public interest groups have conducted a number of studies of pesticide use in schools. The group Public Citizen investigated pest control practices in Texas, Philadelphia, Atlanta, and Washington, D.C. schools (60,145,204,212), and the New York Attorney General's Office studied pesticide use in New York schools (101). These studies surveyed school districts, supervisors, fields keepers, and others for the types of pesticides applied on school grounds and the pests for which they are applied. The State of California is conducting a survey of school district pest management policies, programs, and practices; the results are expected to be released in 1995 (67). **The results of these surveys can, at best, point out only the potential for exposure in school, but they provide no information about exposures or health effects.**

Whatever their value in illuminating certain facets of pesticide exposure, these case reports are not a systematic attempt at surveillance of such exposures or investigations of possible health effects.

TABLE 4-4: Pesticide Exposures Reported in the California Pesticide Illness Surveillance Program (1982–91)

Year	Total cases in schools	Number of students affected	Total agricultural	Total non-agricultural
1982	22	19	744	534
1983	2	0	651	450
1984	5	1	655	432
1985	14	14	883	481
1986	25	22(+)[a]	589	444
1987	54	40	889	866
1988	20	2	874	1,244
1989	16	0	630	1,124
1990	17	0	615	1,372
1991	17	3(+)[a]	592	1,647
Total	**192**	**101(+)a**	**7,122**	**8,594**

[a] Includes case reports of students reporting ill, but the numbers of students affected were not specified.

SOURCES: Office of Technology Assessment, 1994; adapted from unpublished data in the California Pesticide Illness Surveillance Program.

Health Effects

The health effects known or suspected to arise from pesticide exposure are just as broad—spanning from acute poisoning to chronic health effects—as the many uses of pesticides. Unlike many environmental hazards discussed in this report, pesticides are relatively well-tested and their toxicities with certain exposures are rather well-established. Detailed information about the toxicity of specific pesticides is beyond the scope of this report but can be found in the extensive treatments of the subject in widely used texts and reports (10,79,144,152).

Generally, exposures to high concentrations of pesticides can result in acute poisoning. There is ample evidence that exposure to pesticides has resulted in reversible illnesses with symptoms such as nausea, fatigue, vomiting, chills, and headaches; extremely high doses can cause death (109,144). From the available data, fatalities occur very rarely in school-aged individuals.

Far more of a controversial issue than poisoning from large acute exposures, illness may arise from chronic exposure to low doses of pesticides. Such events are not as well documented. Animal studies have associated multiple low-level exposures to pesticides with a variety of disorders, but human data are scant and subject to differing interpretations (79,152,228). This is relevant to school children, since use of pesticides in schools can be an additional source of exposure to children, possibly being additive to non-school exposures (52,218,269).

Some studies show pesticides can cause or are suspected of causing serious, even irreversible, effects to several organ systems. The primary target of many pesticides, especially insecticides, is the nervous system, and studies on the effects of chronic exposures to certain pesticides, such as the organophosphates or carbamates, demonstrate neurotoxic reactions (144,228). Another suspected target tissue is the immune system: certain chemical sensitivities, allergic reactions, and immune deficiencies are attributed to pesticide exposures (152). Other organs thought to be susceptible include the liver, kidney, and lung (79,144,152).

In addition to impacting organ systems, pesticides can affect developing tissues or influence tissue growth, possibly leading to reproductive and developmental problems or cancer. A recent study related home pesticide use with some types of childhood cancer (107); the study lacks adequate exposure data, however. An active area of current research involves the ability of certain pesticides and related compounds to alter the production and metabolism of the hormone estrogen, important in the menstrual cycle and the growth and development of secondary female sex characteristics (32,39).

The evidence of effects on growing and reproducing tissue raises concerns that children may prove more (or less) susceptible to pesticide toxicity. Although few studies have examined whether children and adults respond differently to pesticides, a Congressionally requested National Research Council study found, among other issues, both quantitative and qualitative differences in toxicity of pesticides between children and adults (152). Children absorb more pesticide per pound of body weight; they may receive substantially higher doses than adults, and their immature development may make them more susceptible to toxic effects.

Risks

Because of their many benefits and applications and, according to some (182), the absence of personnel training in alternative nonpesticidal approaches, pesticides will continue to be present in the school environment for the foreseeable future. **Even though the presence of pesticides indicates the possibility of exposure to students, OTA could not find evidence that in-school exposures presented a health threat greater than exposures outside the school environment.** Most exposures that did occur in schools were to school staff, often untrained in pesticide handling and application. Those cases in which students became ill from pesticide exposures resulted almost entirely from poisonings following inadvertent use, an accidental spill, or intentional or unintentional ingestion. Clearly, inadequate data exist on which to base an assessment of risk from poisoning.

However, health effects data for certain pesticides suggest the potential for adverse health effects, and children may be more susceptible to pesticide toxicity with certain pesticides than adults. Moreover, schools may contribute to the cumulative impact of all the exposures a student may receive in his or her daily life. Consequently, the EPA, state agencies, and public and private groups are making efforts to reduce pesticide use in schools. Some researchers suggest that children may be exposed to substantial levels of residential pesticides (107). **Although there are no studies with direct comparisons, the greater amount of time spent at home and the results of the available studies indicate nonetheless that chronic residential exposures are larger, on average, than chronic pesticide exposure in schools** (110).

Other School Materials

In addition to lead and pesticides, other potentially toxic materials can be present in the school environment. This section will consider those agents used for school maintenance and as teaching aids in the classroom. The next section on indoor air quality will cover other materials, such as asbestos and radon, that are primarily considered as indoor air contaminants. Although interest in school toxics increased during the 1980s, the actual literature on this topic remains sparse. Four recent texts for these materials include: *Artist Beware* (128), *The Artist's Complete Health and Safety Guide* (184), *Art Safety Guide* (38), and the *Health and Safety Manual for Schools* (162). These sources document the presence of many potentially toxic substances in schools, but they provide no evidence of exposure to them or any resulting illnesses. Most of the materials discussed here are chemicals used in building maintenance, materials in arts and crafts supplies, and the biological and chemical agents used for laboratory science courses.

Several analysts point to the use of highly toxic chemicals, such as lead, cadmium, and solvents, in school art and science courses as possible public health problems (130,184). The Center for Safety in the Arts (CSA), which is the largest nonprofit clearinghouse on art safety information, has identified a variety of toxic materials used in arts and industrial art classes, such as ceramic glazes containing lead, and paints with solvents and inorganic pigments with heavy metals, e.g., lead, cadmium, chromium, and mercury (128,129,130).

In addition to possible toxics in arts courses, children may be exposed to chemical and biological hazards in elementary and secondary school science classes (130,162). Chemistry labs often incorporate certain toxic materials or materials that can become hazardous by mixing with other compounds or with some other treatment, such as heating. Precautions are necessary in other laboratories as well. Biological courses use various chemicals, such as preservatives for biological specimens. The biological material itself, such as a frog to be dissected in an anatomy course, can be a source of infectious organisms if not prepared and stored adequately. Finally, certain plants can be poisonous, such as jimpson weed, or cause allergies, such as poison ivy.

Exposure and Illness Data

Despite this array of potentially hazardous chemical and biological materials in the classroom and for school maintenance, few reports exist to demonstrate that they are making students ill or that students are even exposed to them. The sparse data offer random case reports of mishandled materials. In fact, CSA maintains that most of the reports they receive of illness in school are of teachers, who have more exposure than students since they teach many arts classes and can have years of exposure. In addition, many arts teachers are also artists and are exposed to these materials at home (130).

In 1992, the AAPCC database reported 4,762 exposures to potential poisons in art and craft materials, including artist paints, pencil, pens and ink, and crayons, to school-aged children, 5-17 years old, but these data do not identify in-school exposures. Despite the lack of in-school exposure and illness data, other studies suggest the presence of toxic materials in school. Public interest groups from various parts of the country surveyed schools in several states and cities for art room safety and health procedures, including the District of Columbia (61,62), New York (6), California (168), Oregon (185), and Massachusetts (126). They documented that some art supplies were inadequately labeled, that certain materials should have been restricted—if not banned—from use by younger children, and that more training was needed for instructors about the safe use of hazardous materials.

These studies contributed to state and ultimately federal legislation (see box 4-3) that requires better labeling of art supplies. Nongovernmental efforts to improve health and safety information also exist. The New York United Teachers, for example, produced a health and safety manual for schools in 1992 (162) that discusses the hazards to which teachers are exposed, their health effects, and methods for controlling them.

Another area of concern is the presence of toxic materials in school arts and industrial arts courses (130,183). These courses, including woodworking, photography, and ceramics, are taught in an estimated 25 percent of secondary schools and a smaller number of elementary schools, according to an estimate of one expert (184)[11]. These courses can expose students to metal dusts, fumes, and wood dust, the last of which has an Occupational Safety and Health Administration occupational exposure limit, based on studies reporting respiratory, irritant, allergic, and carcinogenic effects (however, the rule was overturned in court) (259). Another area of concern are classes teaching photography and photochemical developing. According to Rossol (184), photolabs in elementary and secondary schools usually lack safety equipment and proper ventilation. For the making of ceramics, some hazards include the release during the kiln firing of clay dust, which can contain silica (known to cause fibrosis) and toxic gases such as carbon

[11] The estimates are a subjective evaluation based on the experience of Rossol (184).

BOX 4-3: Labeling of Art Materials

The warnings on art materials and other consumer products came under the jurisdiction of the Consumer Product Safety Commission (CPSC), which administers the Federal Hazardous Substances Act (FHSA). Until 1988, the FHSA required only acute health hazard labeling on art materials.

In the mid-1980s, several states—California, Oregon, Tennessee, Illinois, Florida, Virginia, and Connecticut—passed laws mandating chronic health hazard labeling of all art materials. They also banned the use of toxic art materials in elementary schools.

Faced with variations in laws from state to state, Congress in 1988 amended the FHSA by passing the Labeling of Hazardous Art Materials Act. This law requires art and craft manufacturers to determine the chronic health hazards of their products and place warning labels on those containing such hazards. The act requires all art materials that pose a chronic health hazard to carry a statement that they are inappropriate for children, and the Consumer Product Safety Commission can obtain a court injunction against any school purchasing such materials for use by children in grades six and below. It remains to be seen whether CPSC will take strong action under this provision. The act also directed the CPSC to develop criteria for evaluating the chronic hazards in art materials and preempted state laws on art material labeling. The law went into effect in 1990, and final regulations were published in 1992.

In 1987, as a result of the labeling law passed in California, the California State Department of Health Services published a list of art materials approved for use in elementary schools; this was updated in 1988. Because of budget cuts, the department has discontinued publication of this list.

One industry program has tried to address the question of the toxicity of children's art materials. Since the 1940s, the Arts and Crafts Materials Institute (ACMI) has had a certification program for children's art materials. Participating manufacturers whose products passed a review by a consulting toxicologist could place the AP (Approved Product) or CP (Certified Product) seal of approval of the ACMI on their products. This program is credited with having an enormous effect on reducing the acute toxicity of children's art materials.

Not all manufacturers have participated. Until recently, large ones tended to participate, and smaller ones did not. In the last several years, however, the CP/AP program has greatly expanded.

With mounting concern about chronic health hazards, art material manufacturers developed a voluntary chronic health hazards labeling standard under the auspices of the American Society of Testing and Materials, and the ACMI adopted those standards. Since the approval of art materials does not require actual long-term animal testing, questions have been raised about the chronic health risks of some of these materials.

A California audit of ACMI-approved products resulted in many of these products not appearing on the state's list of approved products because of differing toxicological criteria, inadequate documentation, or differences of opinion over approving materials such as oil paints, which are customarily used with solvents. Many of these problems have since been resolved.

SOURCE: M. McCann, *Artist Beware*, 2nd Ed. (New York, NY: Lyons and Burford Publishers, 1992).

monoxide (183). In addition to art materials, Rossol (184) points out that students may be exposed in home economics courses to fabric dyes, oven cleaners, cosmetics, and hair sprays; school plays, musical events, and other theatrical programs can expose students to scene paints, stage makeup, and theatrical fog and smoke effects generated from machines using glycols and mineral oil.

Science classes and their laboratories can contain toxic materials. An experiment in a Connecticut high school chemistry lab, for example, exposed 22 students and a teacher to mercury vapor (207) as the teacher tried to heat up a mercury-containing mixture. Although the exposures were below levels associated with neurotoxic effects, the incident points to the need for care in handling chemicals in science courses.

While the extent to which students are exposed to these materials is unknown, evidence suggests the need for a greater awareness of the possible health hazards (185). Surveys found inadequate training and education of instructors and poor ventilation in each of the schools and school districts visited (128,130). But because of budget cuts, the California State Department of Health Services has discontinued publication of its list of approved children's art materials. More frighteningly, certain products containing hazardous chemicals are mislabeled. Two surveys of art products on store shelves found a lack of compliance with the labeling requirements of the Federal Hazardous Substances Act, and many of these art supply labels inadequately warn of chronic health effects; however, the studies were of a limited number of products (209,275). The Consumer Product Safety Commission recalled a brand of crayons imported from China (231). These crayons contained enough lead to present a lead poisoning hazard to young children who might eat or chew them; however, the crayons were labeled "nontoxic."

Health Effects

School-aged children routinely use rubber cement, permanent felt tip markers, pottery glazes, enamels, spray fixatives, and other possibly hazardous materials. Educators, supervisors, and parents are often unaware of their potential for adverse health effects, even though in some cases there are adequate or even substantial animal and human studies demonstrating their toxicity. This section briefly describes the health effects data for various classes of materials found in the school environment, but an analysis of the data on specific compounds is beyond the scope of this report.

Some school materials are poisonous, causing acute effects with single exposures. In particular, organic solvents represent a major concern for poisoning, since they can be used in schools even though a single swallow can be fatal to children. Because of their volatility, solvents vaporize into the air; consequently, a major route of exposure is via inhalation, which is covered in the next section on indoor air contaminants. Solvents can also be absorbed by the skin or ingested. For example, methyl alcohol—found in paint strippers and some craft dyes—can cause acute poisoning and even blindness when absorbed through the skin, inhaled as a vapor, or ingested. The many uses and experiences with solvents in the workplace have generated a substantial body of information on the toxicity of solvents (3,228,265). Apart from the toxicity associated with specific agents, solvents act as general depressants of the central nervous system. Acute exposure to high concentrations results in disorientation, euphoria, giddiness, and confusion, progressing to unconsciousness, paralysis, convulsion, and death from respiratory or cardiovascular arrest (3).

There are also concerns about chronic hazards from art materials. For example, there is considerable evidence that toxic encephalopathy may be caused by high-level prolonged and repeated exposure to some organic solvents (65,222,228). Encephalopathy consists of a wasting of brain matter, which leads to expansion of the fluid-filled cavities of the brain, resulting in motor disorders and impaired mental function (228). Nineteen cases of "solvent encephalopathy" were reported in 1980 in children ages 8-14 (97). The children displayed symptoms of behavioral disturbances, coma, muscular incoordination, and convulsions. The investigators determined the cause to be from "glue sniffing" with toluene-containing glue. In addition to neurological problems, solvents can produce toxic effects in the liver, kidney, and heart (3).

Toxic metals with established chronic effects are also found in the classroom and art supplies (7,9,270). One study identified two school-aged children at a psychiatric hospital who had consumed liquid ceramic glaze during the production of ceramic ware (211). The glazes contained lead. In addition to lead (discussed earlier), metals appearing in the classroom include cadmium and mercury, usually as pigment in paints and, as described earlier, mercury is sometimes used in science courses (207). General reviews on the toxic effects of metals can be found in Goyer (71), Clarkson (29), and Fowler (56).

Several case reports detail noncancer chronic health effects in artists and crafts people. Case studies report the adverse health effects of working in photography laboratories (84,86,98). CSA reports a number of illnesses related to exposure to art materials: chemical pneumonia from cadmium-containing silver solders; asthma from pottery kiln gases; lead poisoning from lead-based silk screen printing inks and solvents; skin allergies from dichromate photoemulsions; and hearing loss from noise in industrial arts shops (130). However, the exposures of those people were probably of longer duration and greater intensity than those of students' during the normal hours of school operation. In any case, no available evidence exists to suggest that in-school exposures have caused such chronic effects in students in the classroom.

Risk

The available exposure and illness data in schools consist almost entirely of anecdotal reports of poisoning. Typically, school children can be exposed to mishandled material containing potentially toxic substances. Yet reports of these occurrences are extremely rare. While few students seem to be poisoned in school, the surveys of the school compliance with federal and state laws and regulations concerning the handling of hazardous art materials suggest that many teachers are still poorly instructed on the proper use of these materials, and schools usually lack the resources or the proper instruction to provide classrooms with sufficient ventilation and storage space.

All told, the evidence suggests that potentially toxic materials can be used in schools. **However, OTA could not find a substantial database demonstrating school exposures, let alone data on illness arising from them.** This is not to say they do not occur—they do. However, too little information is available to estimate the likelihood of children becoming ill following school exposures.

INDOOR AIR QUALITY

Although first investigated in the 1970s, indoor air quality (IAQ) emerged as a workplace concern by the mid-1980s, and it has become a much discussed environmental health issue in the 1990s. Concern over indoor air pollution in schools led to hearings before the House Subcommittee on Health and the Environment in the 103d Congress (226). Since most Americans spend a majority of their time indoors, indoor air is considered the major route of exposure to many toxic materials for most people (176,215).

There is no universally accepted definition of indoor air quality (214). As a principle, human comfort has always been the primary focus of the design and operation of ventilation systems for buildings; and comfort is achieved with an appropriate balance among several factors, including temperature, relative humidity, odors, and airflow. A broader definition of acceptable indoor air quality would include consideration of physical, chemical, and biological contaminants.

Indoor air problems can be divided for our purposes into two categories: *thermal environment* and *air contaminants* (214). Satisfaction with the *thermal environment* results from a complex, subjective response to several interacting variables, including temperature, humidity, and air movement. Studies demonstrate that comfort levels for pupils and teachers can differ by 5°F (4). Relative humidity has both direct effects from the impact of relative humidity on physiological processes and indirect effects from the impact of humidity on the growth of pathogenic organisms or on the behavior of airborne chemicals (5). *Air contaminants* consist of particles, vapors, and gases. "Particulates" include tobacco smoke (which also contains vapors and gases), asbestos, allergens (pollen, fungi, insect parts, and feces), and pathogens such as bacteria and viruses (which are discussed later under infectious diseases). Some of the more important vapors and gases include radon, volatile organic compounds (VOCs), and combustion products. While the focus of this section is on indoor air contaminants, the thermal environment contributes to indoor air problems, although its contribution is not as well studied.

Indoor Air Quality Problems in Schools

Many of the indoor air quality problems that occur in schools occur in other types of large buildings, while some are associated primarily with school facilities. Problems common to many large buildings include VOCs, radon, biocontaminants, and asbestos (47). These problems result from the operation and maintenance of school building materials, furnishings, and heating, ventilation, and air conditioning (HVAC) systems. Other problems arise from the conduct of courses in the school curriculum, and include exposure to airborne materials released from art supplies, chemistry and biology labs, wood and metal shops, and locker rooms.

Maintaining acceptable indoor air quality requires an understanding of the dynamics of air entry into the building and air flow within the building (77). IAQ problems in schools usually arise from inadequately designed or maintained HVAC systems, which normally filter out airborne materials and bring in "fresh air" to mitigate the accumulation of toxic gases and particles. Inadequate ventilation contributed to, if not directly caused, a variety of health complaints to the National Institute for Occupational Safety and Health (NIOSH) that were associated with indoor air problems (139).

In addition to inadequate ventilation, air quality problems can arise from contaminants in poorly handled or stored art and science materials, teacher or student smoking areas, or even badly located bus parking or idling areas (47,130,213).

Exposure and Illness

Beyond those of asbestos and radon (discussed below), there are no national surveys of IAQ in schools; however, some state programs exist. To provide information about the nature of current IAQ problems across the nation, OTA reviewed requests made to NIOSH by school teachers and staff for Health Hazard Evaluations (HHEs). NIOSH conducts these investigations on request to determine whether any substance normally found in the place of employment has toxic effects in the concentrations used or found (147). HHEs are not requested by students or on behalf of students. In using NIOSH data, the assumption is that students breathe the same air and are exposed, if at all, to the same contaminants and other IAQ problems as teachers and other school employees. It is likely, however, that the duration of exposure is shorter for students because students change rooms and are outside for part of the day.

NIOSH has completed investigations at 232 schools; 52 cases remain open. The data available to OTA span the years from 1980 to 1993. Requests received prior to 1990 were more likely to deal with specific exposures (e.g., asbestos) than those since 1990, which tend to deal with nonspecific complaints about indoor air quality (216). In 1992, NIOSH conducted a series of investigations, termed the *blitz cases,* into IAQ problems in response to heightened public awareness of such issues—initiated by a public news broadcast, which provided a toll-free phone number to request more information on IAQ and to file requests for an HHE. From October through December 1992, NIOSH randomly selected 160 requests—out of about 600—ensuring geographic and socioeconomic distribution so that the results would not represent the problems of a particular community or region. Of these evaluations, 26 were done in schools. The surveys were completed by spring and summer 1993 (42).

The blitz data are biased in that they were collected from schools where complaints were registered. They are not a random sampling of schools in general, nor are they informative about the frequency of IAQ problems. Most complaints about in-school IAQ would not be reported to NIOSH but would instead be directed at the school, school district administration, or individuals with responsibility for maintaining school facilities; thus, the blitz data may not even be representative of schools with IAQ problems. Nevertheless, the information about health effects and sources of exposure illuminates problems in some school settings. These cases provide a picture of the current nature of school IAQ problems that is not matched by other studies or sources of information

Table 4-5 presents the health effects and sources of exposure cited as reasons for justifying an investigation by NIOSH. The classifications are rather arbitrary since the effects are often complicated, with multiple symptoms observed per complaint. Bronchitis and asthma, for instance, are cited as respiratory problems, yet they may be the result of or aggravated by allergic reactions. Moreover, the health effects are identified by employee self-reporting and usually not confirmed by a medical professional.

TABLE 4-5: NIOSH Investigations of Contaminant Exposures in 26 Schools

Health Effect	Number of Complaints	Source	Number of Complaints
Nonspecific illness	(9)	Ventilation problems	(5)
SBS	2	Stale air	4
Fatigue/malaise	6	CO^2	1
Nausea	1		
Unspecified complaints	(3)	Physical	(9)
		Temperature	1
		Dust	3
		Asbestos	5
Irritation	(12)	Chemical	(2)
Throat	4	Formaldehyde	1
Skin/rash	1	Lead paint	1
Eyes	7		
Neurological	(19)	Fumes	(6)
Headache	12	Odors	2
Numbness of extremities	1	Fuel (coal)	1
Dizziness	5	Photocopy machines	1
		Sewage	1
		Swimming pools	1
Respiratory	(35)	Biological	(5)
Shortness of breath	1	Bacteria	1
Respiratory ailments	14	Mold/mildew	3
Asthma	4	Fungus	1
Bronchitis	2		
Sinus	11		
Colds	1		
Immunological	(3)		
Allergies	3		
Infections	(3)		
Legionnaires	1		
Pneumonia	1		
Strep throat	1		

SOURCES: Office of Technology Assessment, 1994; based on data from the National Institute for Occupational Safety and Health, Health Hazard Evaluation Program, 1994.

Some requests pointed to specific contaminant sources as the possible basis of various problems. Some reports implicated a physical hazard, such as dust and asbestos, or chemical agents, especially fumes from multiple sites. Other requests cited biological problems such as mold and mildew as sources of either potential problems or the observed illness.

The requests complained about such conditions as stale air, bad ventilation, and lack of fresh air. Often these arise from ventilation problems that result in uncirculated air and elevated amounts of carbon dioxide, which is expired by the dwelling's inhabitants. These conditions generate a sense of discomfort or uneasiness and stem from increases or decreases in temperature, humidity, and air dryness, arising from the condition of the thermal environment.

As expected, most requests for a NIOSH-conducted HHE cite respiratory problems. Neurological effects, headache, fatigue, and dizziness, and throat and eye irritation are also frequent complaints. These represent the symptoms usually associated with sick building syndrome (described below). **This portrait of the health complaints suffered in schools reflects the subjective and rather nonspecific nature of the health effects resulting from IAQ problems.**

Health Effects

There are two distinct classes of IAQ problems: "sick building syndrome" (SBS) and "building-related illness" (BRI) (47,48,251). SBS is used to describe situations in which adverse, often general and nonspecific, health effects are associated with a building, but the exact cause is unknown. In documented cases, reported SBS symptoms range from headache, fatigue, eye irritation, runny nose, scratchy throat, fever, dizziness, nausea, and chest tightness to breathing difficulty (124). An important aspect of SBS is that the symptoms lessen or disappear completely as occupants leave the building. The symptoms found in SBS are most likely to represent a nonspecific response to an array of environmental stimuli, the particular components of which vary from office to office (124,251).

This nonspecific and subjective nature of SBS symptoms makes their reporting subject to psychological and social factors (251). In particular, studies demonstrate that symptoms of SBS are associated with high stress levels (18,138). General dissatisfaction with the workplace can, by itself or coupled with IAQ problems, lead to complaints about air quality. This statement is in no way intended to convey the idea that health effects from IAQ problems are psychosomatic. Rather, it is intended to point to the difficulties of teasing out relationships among exposures, illnesses, and other factors. In a highly publicized case in 1991, a school in Northern Virginia reported many cases of fainting, headaches, and lightheadedness among its students. Numerous investigations into air quality and the presence of air contaminants found nothing specific to explain these effects, beyond minor technical problems with the ventilation system. Since many cases (138 reports of fainting) occurred in less than 1 percent of the student population, and 75 percent in the same five girls, some experts concluded that the culprit was a mass sociogenic illness in response to unusual physical or psychological stress; others did not agree and expected that the culpable air contaminant would eventually be found (58).

In contrast to SBS, building-related illness refers to adverse health effects associated with known etiologies, including hypersensitivity illnesses, infections, and illnesses or complaints related to specific chemical or physical agents. Specific signs (not just symptoms), are associated with these illnesses. Some examples of possible building-related illnesses are allergic rhinitis, allergic asthma, hypersensitivity pneumonitis, Legionnaires' disease, Pontiac fever, and carbon monoxide poisoning (176). Legionnaires' disease and Pontiac fever are both caused by *Legionella* bacteria. Sources of carbon monoxide include vehicle exhaust and inadequately ventilated kerosene heaters or other fuel-burning appliances. Some of the HHEs attributed health effects to spilled agents, solvents, or mold and mildew.

Specific Indoor Air Contaminants

Although many possible air contaminants may exist in the school environment, this report pays particular attention to asbestos and radon. These are not the only agents in indoor air associated with health effects, but they are among the best studied and of most concern. To a lesser extent, OTA examined the available data on environmental tobacco smoke, volatile organic compounds, combustion byproducts, and biologic organisms. OTA's summarization of this material does not reflect their diminished importance but rather the paucity of in-school data. Although some information exists about the presence of all of these agents in schools, there is little direct evidence linking in-school exposures to the diseases discussed. Instead, information about linkage comes from hazard identification data from studies in highly exposed occupational populations—insulation workers for asbestos risks, miners for radon risks, etc.—and from studies of other nonstudent populations, as well as animal studies.

Asbestos

"Asbestos" is a term applied to six different mineral fibers that are mined in many parts of the world. Because of its properties—durability, resistance to chemical and microbial attack, and most importantly, resistance to fire and abrasion—asbestos-containing materials were the preferred product for many applications in buildings of various kinds, including schools. Indeed, about 31,000 primary and secondary schools in the United States have asbestos-containing building materials in some form—insulation and fire protection in heating plants and distribution systems, sprayed-on material for structural fire protection, asbestos-containing tiles, and asbestos-containing plasters, where the asbestos contributes to sound dampening as well as fire resistance (80).

For all of its useful properties, asbestos has a definite downside. In the 1930s, scientists and physicians noted that occupational exposures to high levels of asbestos over long periods of time were associated with asbestosis (a chronic and often fatal lung ailment), and some connections were drawn between exposures to asbestos and the occurrence of lung cancer. In 1955, Doll (45) tied down that association by demonstrating that lung cancer levels were far higher than expected in populations of men who worked with asbestos. Five years later, Wagner et al. (264) reported that exposures to asbestos were associated with increased occurrence of mesotheliomas (cancers of the lining of the chest or abdomen). In the years that followed, a number of scientists replicated those findings. The type of asbestos most commonly used in buildings—chrysotile—is generally considered to present less of a cancer risk than other types. Also, most lung cancer cases among asbestos workers occur in smokers; the risks for nonsmokers are much less. Finally, cancer risk decreases with decreasing exposures (80).

Several efforts were made to estimate the contribution of asbestos exposure to the total cancer burden of the country. In 1978, 10 government scientists (19) estimated that occupational exposures to asbestos were associated with 10 to 18 percent of all cancers in the United States. Subsequently, other scientists reduced that estimate to about 1 to 3 percent (68,173), but asbestos remains the leading occupational cause of cancer.

Knowledge of the adverse health consequences of exposures to asbestos, coupled with information about its presence in buildings, led a number of people to call for regulations on asbestos-containing building materials. In 1978, the Governor of New Jersey asked the EPA to issue regulations for the control of asbestos in public buildings. Although EPA refused to act on that petition, it initiated a process that resulted in the 1982 rule "Asbestos: Friable Asbestos-Containing Materials in Schools: Identification and Notification" (243).

In-School Exposures

The EPA rule required school systems to inspect their buildings for the presence of asbestos-containing materials and to notify parents if such materials were found. As the presence of asbestos was verified and parents and teachers were informed, arguments flared up about: 1) how to measure or calculate asbestos levels in schools; 2) the risks associated with exposure; and 3) the appropriate methods to reduce exposure.

Asbestos is present in some schools, as in other buildings, but its mere presence does not threaten health. To cause a risk to human health, asbestos fibers must be released from insulation, plaster, or other materials into the air where they can be inhaled.

EPA's (242) earliest estimates of the concentrations of airborne asbestos in schools were derived from measurements made by French scientists in workshops, office buildings, an aircraft hanger, and other buildings. By 1983, EPA had obtained measurements of asbestos in the air of several schools. The French measurements and the early EPA measurements were based on an "indirect" method of preparation. Samples of air were pulled through a filter fine enough to retain asbestos fibers and other airborne materials, and the collected materials were subjected to several manipulations before being examined in an electron microscope in such a way that the weight of the asbestos in the sample could be determined. The method was never validated as a measure of airborne asbestos or of asbestos that might be inhaled and present a cancer risk.

In any case, EPA placed little reliance on any measure of airborne asbestos in determining exposure levels. Instead, it endorsed the use of various visual clues as a guide to estimating the likelihood of exposures from disturbance of asbestos-containing materials (69,244,245,274). The visual clues did not, however, predict airborne concentrations of asbestos or correlate with measured levels, even when samples were prepared by the indirect method.

The "direct" method of sample preparation is used in workplaces where asbestos is or was a recognized risk. A measured volume of air is drawn through a filter, and a microscope is used to count the number of asbestos fibers caught on the filter. This is the accepted process for measurements in schools and buildings as well and the one now endorsed by EPA for measuring airborne asbestos levels. Table 4-6 summarizes the results of measurements of airborne asbestos in schools. Wilson et al. (274) note that many of the school rooms for which data are available were chosen for sampling because they were involved in litigation or because the asbestos-containing materials appeared to be in bad shape. The data in table 4-6 may, therefore, be higher than average asbestos exposures.

The Occupational Safety and Health Administration (OSHA) currently enforces an occupational exposure limit of 0.2 fiber per cubic centimeter (f/cm^3) of air where the fibers are 5 micrometers (μm) or longer. The measured average concentrations of such fibers in schools are one-thousandth or less of the occupational limit. Table 4-7 presents summary values for measurements of asbestos fibers in public buildings, school buildings, urban air, the OSHA standard, and the levels of asbestos in workplaces that have been associated with cancer. (The asbestos in outside air can arise from weathering of asbestos-containing minerals, from automobile brakes and other friction products, and perhaps from other sources.)

TABLE 4-6: Average Levels of Airborne Asbestos in Schools

Study	No. of schools	Total No. of fibers	Fibers >5 μm (f/cm^3)[a]
Corn et al., 1991	71	0.020	0.00023
Lee et al., 1992	177	0.040	0.00018
Lee et al., 1992	78	0.008	0.00008 (univ. bldgs)

[a] Total No. of Fibers include fibers smaller than 5 micrometers (μm), as well as larger fibers. The smaller fibers represent less risk. f/cm^3 = number of fibers per cubic centimeter of air.

Repeated demonstrations of low concentrations of asbestos inside buildings led EPA (250) to adopt "operations and maintenance" policies for the management of asbestos. These policies recommend identifying asbestos-containing materials, removing any that are in poor repair, and providing instructions and equipment to workers (electricians, telephone and computer technicians, custodians, etc.) who may come into contact with them so as to reduce their exposures. The overall thrust of this policy is that asbestos-containing materials in good condition can be managed in place, not torn out (36,70,108,250).

EPA's recommendation to manage asbestos-containing building materials in-place came about after the accumulation of many measurements of airborne asbestos fibers. There was certainly no serious dissent from the conclusion that occupational exposures involving high-dose, long-duration inhalation of asbestos fibers could cause lung cancer, mesothelioma, and asbestosis. There was also no basis on which to quarrel with statements that asbestos-containing materials were present in many schools. To the extent that those materials might release significant quantities of asbestos fibers into the air, they were a risk to students, teachers, and staff. Measurements showed, however, that the average levels of asbestos in buildings, including schools, differed little from concentrations in outdoor air. Furthermore, these measurements, made in many buildings over a period of several years, provide no indication of episodic releases of high concentrations of asbestos.

EPA has never established a particular concentration of airborne asbestos that, when exceeded, requires corrective actions (abatement), and its visual inspection algorithm has never been validated as being predictive of airborne levels or exposures. In 1983, EPA, in fact, reported that its inspection algorithm was not predictive, but it did not offer another form of inspection, such as measurement of airborne asbestos as an alternative. In 1985, without reference to studies that supported use of the algorithm, EPA reversed its position and endorsed its use (274) (see box 4-4). The importance of the inspection method and controversies about it apparently declined with the publication of the 1990 EPA guidelines that recommended management in place for asbestos-containing building materials in good condition.

EPA has, however, established 0.005 f/cm^3 (where all fibers greater than 0.5 μm are counted) as the acceptable level for reoccupation after any asbestos abatement project is complete. Although that level was exceeded in some school buildings (see table 4-6), its meaning for risk remains unknown, because all the risk calculations are based on measurements of fibers 5 μm and greater in length.

Perhaps the most famous asbestos-in-schools episode occurred in New York City in 1993 when an "asbestos scare" delayed the opening of schools (274). In fact, the asbestos scare grew from false reports of inspections that were never made and some generalized fears about asbestos (44).

Abatement

Since the reports of asbestos in schools, many local education agencies (LEAs) have instituted control methods, and EPA has partially financed some of those efforts. Under the provisions of the Asbestos School Hazard Abatement Act (ASHAA) of 1985 and its 1990 re-authorization,

TABLE 4-7: Levels of Airborne Asbestos

Source of samples	Concentration (f/cm^3)[a]
Urban air, range	0 to 0.001
Typical high urban air	0.0001
Public buildings	0.0002
School buildings[b]	0.0002
OSHA standard	0.2
Worker exposures associated with cancer	10.0

[a] Fibers greater than 5 μm.
[b] From table 4-6.

SOURCES: Office of Technology Assessment from Whysner et al. 1994, which was based on Health Effects Institute-Asbestos Research, 1991.

BOX 4-4: Salient Features of the EPA Guidance Documents[a] for Management of Asbestos in Schools

Orange (1979)

- The document (in two parts, 1 and 2) addressed potential problems and risks associated with loosely bound, asbestos-containing ("friable") surfacing materials.
- Health risk determination was based on a subjective, visual inspection.
- Air sampling is called "inappropriate."
- Recommended removal, enclosure, or deferred action.

Yellow (1982b)

- Based on a review of 600 buildings in the Midwest, a visual algorithm of risk analysis ("numerical exposure assessment") is put forward. Health risk was gauged by visual inspection and "exposure assessment."
- Among important factors in risk evaluation were accessibility, friability, visible damage, proximity to air ventilation systems, and others.
- The document detailed the inadequacy of air monitoring. No recommendations are made for improving or acquiring an asbestos-in-indoor-air database.

Blue (1983a)

- This document maintained a focus on friable asbestos products. In addition, the building owner was encouraged to report the presence, and undertake periodic inspection, of nonfriable asbestos materials to ensure they were in good repair.
- Asbestos removal as an abatement strategy was described as the ". . . only control measure which can guarantee elimination of asbestos exposure."

Green (I) (1983b)

- The existing inspection algorithm was found to be invalid as an index for gauging exposure to airborne asbestos. The amount of asbestos contained in a bulk material was also invalidated as a predictive index of exposure.
- Acknowledges that all the previous factors that guided asbestos inspectors in the gauging of hazard were invalid as exposure indices.

Silver (1984)

- Further focus on the use of air sampling. Both optical and transmission electron microscopy techniques were detailed and compared. Both assays, made after abatement, were to be used for approval of abatement contractors performance.
- Phase-contrast microscopy levels were to be no higher than 0.01 fibers/ml; TEM values were to be "no larger that the average of measured levels outside the work site."

Purple (1985)

- Restriction extended to asbestos containing material in general.
- Algorithm strategy impeached in the Green Book (I) returns as basis for determining potential for fiber release.
- Role of air sampling monitoring restricted to post abatement evaluation.

Green (II) (1990)

- Asbestos hazard is dose dependent, i.e., low dose associated with low risk. Asbestos removal can lead to increased exposure to building occupants.

[a]The documents are commonly referred to by the color of the report's cover.

SOURCE: R. Wilson, et al., "Asbestos in New York City Public School Buildings—Public Policy: Is There A Scientific Basis?" *Regulatory Toxicology and Pharmacology* 20:161–169, 1994.

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EPA has provided $435 million to 1,428 LEAs for use in 3,262 abatement projects. According to EPA, the completion of those projects has eliminated 38 million weekly exposure hours of students and school employees to asbestos (258). In keeping with EPA's practice of relying on visual inspection to indicate the presence of a hazard rather than measurements of airborne asbestos that provide information about the risks of exposure, it is impossible to translate EPA's reductions in exposure hours to estimates of risk reduction.

EPA's analysis of expenditures show that grants were made soon after ASHAA's passage in 1985 for the removal of asbestos from what were classified as the most serious hazards. With the passage of time, the most serious hazards were abated, and in the early 1990s (1990-93, when the ASHAA financial assistance program funding ended), more funds were awarded for less serious hazards. Again, EPA's judgments of seriousness are based on visual inspections, and they provide no definite information on levels of exposure.

EPA funding was not essential to abatement. The agency surveyed LEAs that had failed to qualify for ASHAA assistance and found that they had carried out 68 percent of the projects using their own funds (258). Among the unfunded projects, greater attention was given to the most serious problems; fully 82 percent of those projects were reported to EPA as completed. In summarizing its sponsorship of abatement procedures, EPA concluded that ASHAA funding had been important in abating hazards, that the most serious hazards had received the most attention, and that abatement activities would continue in the absence of ASHAA funding. OTA did not attempt to estimate the total amount spent on asbestos removal and control in schools, but it is surely much more than the $435 million spent under ASHAA.

Risk

Mossman et al. (140) and Corn et al. (37) calculated the risk of lung cancer and mesotheliomas from measured concentrations of asbestos in schools in the absence of any abatement. EPA estimates that there is asbestos-containing materials in about 40 percent of public and private elementary and secondary schools (80). Assuming that the proportion of students attending those schools is the same as the proportion of those schools, the calculated lifetime risks from exposures to asbestos levels of 0.00017 -0.00024 f/cm^3 over a period of five to six years range from 0.3 to 6.5 cancers per million people. This is equivalent to an estimated two to 60 lung cancers per year, out of the entire school population of 46.4 million students (89).

These risk calculations include the assumption that some risk of cancer and mesothelioma results from any dose of asbestos, no matter how small. There is, in fact, a debate over whether very low doses pose any risk at all (140), but the so-called "linear, no threshold" model typically used to evaluate exposure risks in the U.S. holds that risk decreases with dose and does not reach zero until the dose is zero. If, however, a "threshold dose" must be crossed before there is actually any risk, then the calculated risk represents an overestimate. Although it is impossible to know if the calculated numbers are correct (140), they probably represent an upper bound on risk.

Appearance of Cancer and Detection

There is a long lag (usually 20, 30, or more years) between the first recorded occupational exposures to asbestos and increases in asbestos-related cancers. It must be assumed that any cancers that might result from in-school exposures would occur after a similar lag.[12] One reason for this statement is that occupational exposures to asbestos caused a threefold increase in mesotheliomas in North American men, but no detectable

[12] Any lung cancers from in-school exposures, whatever their number, would go undetected among the large number of lung cancers (about 135,000 per year) in the U.S. population. There is no way of saying whether or not a small fraction of those cases was caused by asbestos in schools. Although mesotheliomas are far more rare (about 1,500 cases per year), any cases caused by in-school exposures are likely to go unrecognized.

increase in women during the same time period (131). Exposures of women surely increased during that time because of asbestos carried home on men's work clothes and on their bodies, as well as exposures inside asbestos-containing buildings, but these were not sufficient to affect mesothelioma rates in women. Similarly, any effects of in-school exposure would be unlikely to affect measured mesotheliomas rates.

Although analyses of the histories of people who develop lung cancer or mesotheliomas could be undertaken, they should be attempted only after careful analysis of the power of the studies to detect school-related asbestos risk. Most likely, no study could provide such information even if the harm predicted by risk assessments did occur.

Radon

The Environmental Protection Agency and the Department of Health and Human Services (253) as well as several scientists (120,154) have calculated that environmental exposures to radon are associated with about 13,000 to 15,000 lung cancer deaths annually. That risk, based on studies of underground miners who were exposed to radon in the course of their work, is the largest cancer risk that the EPA associates with any environmental exposure (230).

Radon is a naturally occurring radioactive element. Uranium, which is found throughout the earth's crust, decays to ^{226}Radium, which, in turn, decays to the gas ^{222}Radon. The radon gas can move from soil and rocks into air and water, and through air and water into homes and other buildings. Radon is concentrated inside buildings because structures retard its dilution into the enormous volume of outside air, and the "environmental exposures to radon" mentioned in the paragraph above are exposures inside residences. Based on measurements of radon around the nation, EPA and HHS (253) conclude that the average outdoor radon concentration is about 0.4 pCi/L and the average concentration inside residences is about 1.3 pCi/L, or about three times higher.

EPA has established 4 pCi/L as an "action level" (230), and it recommends that actions be taken to reduce any inside radon concentration higher than that level. EPA also estimates that about 5.8 million of the nation's approximately 100 million homes have radon concentrations ≥ 4 pCi/L. The agency's guide for homeowners notes that reducing indoor concentrations "below 2 pCi/L is difficult" (253), and that levels "below 2 pCi/L are currently not achievable at reasonable costs in 20-30 percent of homes initially above 4 pCi/L" (187).

Despite the size of the risk associated with indoor radon, there is no direct proof that exposures to indoor radon have increased cancer rates. As summarized in Lubin (118), Lubin et al. (120), and Samet (190,192), studies of people who lived in homes with different concentrations of radon fail to confirm an association between living in homes with higher radon levels and higher lung cancer rates. However, this is not surprising. An epidemiological study to determine whether a cancer increase is associated with environmental radon would be so large and complex (119) that it has never been undertaken, nor is it likely to be undertaken. While a direct, epidemiological approach to better understand the level of risk associated with environmental radon is probably impossible, measurements of exposures to environmental radon are used as the basis of determining risks. The school is part of the student's environment, and radon concentrations in school contribute to the risk that also includes exposures at home and elsewhere.

Radon Levels in Schools

Both the Superfund Amendments and Re-authorization Act of 1986 (P.L. 99-499; §118 (k)) and the Indoor Radon Abatement Act of 1988 (P.L. 100-551; §307) directed EPA to conduct surveys of radon concentrations in schools (as well as in other buildings). In response, EPA produced the *National School Radon Survey: Report to Congress* in October 1993 (257).

EPA made short-term radon "screening measurements," using charcoal canister radon detectors, in 927 public schools over seven-day periods during February and March 1991. EPA also made long-term radon measurements of five months' duration using alpha-track detectors (ATDs) in 100 schools over the period December 1990 to May 1991. As part of the long-term study, EPA also obtained seven-day charcoal canister readings from the same rooms in which ATD readings were made to examine the reliability of the short-term measurements in predicting levels measured by long-term tests. EPA placed detectors only in "ground-contact" rooms in the short-term study and in both ground-contact rooms and rooms on other floors in the long-term study. Classrooms, cafeterias, gymnasiums, and offices were sampled in both the short-term and long-term surveys.

Table 4-8 presents some of EPA's results about the frequency of rooms with various levels of radon. As can be seen, the short-term screening measurements indicate that 2.7 percent (± 0.5 percent, not shown on table) of the tested school rooms had radon at concentrations ≥ 4 pCi/L. The percentage of rooms at concentrations ≥ 4 pCi/L as determined by the long-term measurements was 1.5 percent (± 1.2 percent, not shown on table). The difference between 2.7 and 1.5 percent is almost a factor of two, but the standard errors of the two measurements overlap; thus, as EPA points out, ". . . there is no statistical difference between the two estimates" (187).

EPA (187) notes that the two types of measurements are useful for different purposes. The short-term tests ". . .are very useful in indicating whether a particular room or building is either above or below the action level of 4 pCi/L thereby requiring mitigation." In contrast, "long-term measurements are more representative of year-long radon levels." These statements confirm that the long-term measurements are the important ones for making decisions about risks, which are based on cumulative exposures over a lifetime. The EPA Science Advisory Board (205) draws a sharper distinction between the two kinds of tests and urges EPA not to portray the results of the short-term tests as being indicative of either actual radon concentrations or estimates of exposure unless the short- and long-term measurements are shown to be related.

Whether short-term measurements are relied upon, as EPA (257) did in its report to Congress, or long-term measurements are used, which would reduce exposure estimates (see table 4-8), round-the-clock measurements—obtained with both methods—produce overestimates of exposures in schools (117,206):

1. The radon measurements were made continuously day and night for seven days (short-term) or five months (long-term). During times that students were present, the heating, ventilation, and air conditioning (HVAC) systems were in operation and there were many openings of doors and possibly windows. The exact effects of HVAC are not well described, but they probably dilute airborne radon concentrations by mixing together air with different radon concentrations so that, in general, few rooms are at ≥ 4 pCi/L, even in schools that have one such room. EPA's short-term measurements confirm that: Of 927 tested schools, 179 had at least one room at ≥ 4 pCi/L radon. Of those 179, 51 percent had one or two rooms at 4 pCi/L, 22 percent had three, four, or five such rooms, and 5 percent had six or more such rooms.
2. Opening of doors and windows dilutes inside radon concentrations. Since those openings are largely restricted to the, say, eight hours of the day, five days a week that students are present, accumulating radon measurements over the 16 hours of each of the five days in a school week and two days of the weekend when students are not present results in an overestimate of the radon concentration experienced by students.
3. All the measurements were made in winter months when northern schools are likely to be closed more tightly than in the fall and spring. This would tend to increase measured concentrations. Page (167) points out that the opposite effect might be true in southern schools in the sample, which were also measured during the winter months, when the schools are likely

TABLE 4-8: Measurements of Radon Levels in Schools and Estimates of the Number of School Rooms at Different Levels

Results from short-term screening measurements in ground-contact schoolrooms

Radon concentration (pCi/L)	% of rooms at concentration	Est. no. of U.S. schoolrooms at concentration
< 2	91.0	2,495,000
< 4	97.3	2,668,000
≥ 4	2.7	74,000
≥ 10	0.4	11,000[a]
≥ 20	0.1	3,000[a]

Results from long-term measurements in ground-contact schoolrooms

Radon concentration (pCi/L)	% of rooms at concentration	Est. no. of U.S. schoolrooms at concentration
< 2		not available from EPA
< 4	98.5	2,701,000
> 4	1.5	41,000
> 10		not available from EPA[b]
> 20		not available from EPA[b]

SOURCES: Office of Technology Assessment, 1994 based on USEPA, 1993. National School Radon Survey: Report to Congress except data marked with [a], which are from copies of slides, entitled "National School Radon Survey Results" from USEPA and dated 1992 (USEPA 1992b). [b]Number of long-term measurements was too few to produce "a statistically-[sic]significant estimate for the number of schoolrooms . . . with levels greater than 10 or 20 pCi/L," according to EPA. Three rooms had readings > 10 pCi/L and 1 room had > 20 pCi/L (Rowson, 1994a).

to be more open than during the hotter, air-conditioned months.

4. Normal activities further reduce students' exposures. Elementary school students spend some of most days outside, reducing their in-school exposures, and students in middle school or junior high school and above move from room to room during the school day.

The measurement conditions probably lead to overestimates of the radon concentrations encountered by children in schools, and the use of short-term measurements provides more information about short-time conditions than about year-long exposures. Both affect the reported measurements, and both almost certainly contribute to exposure estimates that are higher than if measurements were made only during the times that schools are in use and with measurements collected over longer time periods. The use of long-term measurements would eliminate the second source of possible error.

As might be expected, there is some association between classroom radon concentrations and the potential for radon exposure in different geographical areas. As shown on table 4-9, schools with rooms of ≥ 4 pCi/L are more likely to be found in areas that EPA has classified as having high or medium potential for radon exposures based on results of measurements in homes. The percentage of schoolrooms at ≥ 4 pCi/L radon in the high potential exposure areas is 6.8, 2.5 times higher than the percentage in the medium areas, and fully 8.5 times higher than the percentage in the low areas. The relationships between areas with different radon potentials and schoolrooms at ≥ 10 and ≥ 20 pCi/L do not fit so neatly, but there are very small numbers of those rooms, especially at ≥ 20 pCi/L.

EPA (257) draws attention to the finding that 57 percent of schoolrooms with radon concentrations ≥ 4 pCi/L are located in areas other than those classified as having high potential exposures. Nevertheless, the chances that a schoolroom will be ≥ 4 pCi/L are highest in the high exposure areas, less in the medium exposure areas, and lowest in the low areas, and a survey that focused on high exposure areas first would be the most efficient in identifying rooms at ≥ 4 pCi/L.[13] Based on short-term screening tests, EPA (257) reported that one school had at least one room ≥ 20 pCi/L and that there were 35 rooms ≥ 20 pCi/L. Table 4-9 demonstrates that one such room was from a high potential exposure area and one from a low area. The remaining 33 rooms ≥ 20 pCi/L were in nine schools from the medium areas; if those rooms were distributed randomly in the nine schools, each school would have had about four rooms at ≥ 20 pCi/L radon. EPA (257) reported that six schools with rooms ≥ 20 pCi/L were retested with long-term techniques. According to Phillips (174), readings of ≥ 20 pCi/L were verified in five of the six schools (in the sixth, the canister used for the original reading appeared to have been tampered with). If the frequency of rooms over 10 pCi/L were the same with both the short-term screening measurements and the long-term measurements (0.1 percent), only four such rooms would have been found in the survey with long-term measurements, and, in fact, three were found (186).

OTA used the results from EPA's measurements in 31,400 schoolrooms to estimate the total number of schoolrooms in the U.S. at ≥ 4, ≥ 10, and ≥ 20 pCi/L radon in regions of different potential radon exposures. As can be seen in table 4-10, if the EPA sample is nationally representative, about 74,000 schoolrooms in the nation are ≥ 4 pCi/L; about 13,000 are ≥ 10 pCi/L; and about 3,000 are ≥ 20 pCi/L.

In its request for EPA's survey of radon in schools, Congress did not ask the agency to assess exposures in schools; instead, it asked that EPA measure radon concentrations. Assessing exposures is more difficult. It could have involved tracking students through the schools and estimating their time in rooms of different radon concentrations. While that was not done, it is possible, from the data collected by EPA, to calculate average in-school exposures.

In-School Exposures

Exposure is a function both of intensity and duration of exposures. EPA's *National School Radon Survey* (257). provides some information about

TABLE 4-9: Schoolrooms at ≥ 4 pCi/L Radon in Areas of Different "Radon Potential" as Determined by Short-Term "Screening" Measurements

EPA's radon potential classification	No. of rooms sampled	≥ 4 pCi/L (%)[a]	≥ 10 pCi/L (%)[b]	≥ 20 pCi/L (%)[b]
High	5,602	380 (6.8)	34 (0.6)	1 (0.02)
Medium	15,995	431 (2.6)	95 (0.6)	33 (0.21)
Low	9,756	78 (0.8)	20 (0.2)	1 (0.01)
Total	31,353	889 (2.7)	149 (0.4)	35 (0.11)

[a] From U.S. EPA, 1993.

[b] Based on EPA's slide presentation dated 1992, U.S. EPA 1992b.

SOURCE: Office of Technology Assessment, 1994.

[13] It is possible to make more accurate classifications of radon potential areas, sharpening the boundaries between "high" and "medium" areas, for instance. That might better the correlation between radon potentials and measured concentrations.

TABLE 4-10: Calculated Numbers of Schoolrooms ≥ 4 pCi/L Radon in the U.S. Based on Short-Term "Screening" Measurements

EPA's radon potential classification	No. of schoolrooms	≥ 4 pCi/L[a]	≥ 10 pCi/L[b]	≥ 20 pCi/L[b]
High	442,000	30,100	2,700	88
Medium	1,330,000	35,900	8,000	2,800
Low	971,000	7,800	2,240	97
Total	2,743,000	73,800	12,940	2,985

[a] From EPA, 1993.
[b] Calculated from data in table 4-9.

SOURCE: Office of Technology Assessment, 1994.

the intensity of potential exposures in schools. Accepting EPA's collected data concerning exposure intensities leaves the problem of estimating exposure duration. Based on the short-term screening measurements, EPA (257) estimates that about 20 percent of schools have at least one room at ≥ 4 pCi/L. Therefore, students in the other 80 percent of schools will spend no time at concentrations above 4 pCi/L.

Since about half of the schools with any room at ≥ 4 pCi/L as determined by short-term measurements have only one or two such rooms, many students in those schools will never sit in such rooms. Nevertheless, saying that many students will never sit in a classroom at ≥ 4 pCi/L does not provide information about the exposures to those who do or will. To make those projections requires some assumptions about time spent in classrooms.

EPA (254) calculates that reducing all radon exposures that are now > 4 pCi/L to 4 pCi/L would eliminate 2,100 lung cancer deaths annually—1,500 deaths in smokers, 500 in former smokers, and 100 in never-smokers (230). This reduction would leave unaddressed 11,500 of EPA's estimated 13,600 annual lung cancer deaths from radon. Reducing all residential exposures now ≥ 4 to 2 pCi/L would result in saving an estimated 3,100 annual lung cancer deaths, leaving a residual of 10,500 annual deaths. Such reductions are of little relevance to the majority of people living in the United States, where average concentrations in schoolrooms (0.8 pCi/L) and in homes (1.25 pCi/L) are less than 2 pCi/L.

Many of the deaths estimated to result from radon exposure appear unavoidable. In addition to the difficulties encountered in trying to reduce some in-home exposures from > 4 pCi/L to < 2 pCi/L, about 3,300 annual lung cancer deaths are associated with exposure at the average outside radon concentration of 0.4 pCi/L, and it is impossible to reduce exposures below that.

In-School Risks

It is possible to estimate the risk from in-school exposures. Because radon exposure is generally unavoidable, most estimates are based on lifetime exposures. However, for the purpose of comparing in-school risks from radon to other school risks, which are based on annual figures, OTA calculates the cancer deaths resulting from exposures to average in-school radon levels. These values are compared to average residential exposures and other exposures. These are estimates; there is no way of knowing the number of cancers at one time since it may take many years—10, 20 or more years—before cancers may occur, and these deaths will be in addition to those lung cancers occurring each year. The use of average exposure figures fails to capture the distribution of risks, which will vary—some school children will be at greater risk, others at less.

Assuming, as EPA does, direct proportionality between exposures and risks when exposures are between 0.4 and 20 pCi/L, OTA calculates the following cancer risks from average in-school exposures for a single school year. EPA and DHHS (253) calculate that about 29 out of every 1,000 smokers exposed to 4 pCi/L of radon for 70 years will develop lung cancer and that about two out of every 1,000 nonsmokers exposed at that level will develop lung cancer. For smokers, the calculated annual risk for one year's exposure at 1 pCi/L results in about 104 cancers per million people; for nonsmokers, the risk is 7.1 cancers/million. These values can be used to estimate risks at different exposure levels.

Given the importance of smoking in the risk of lung cancer, this report makes certain assumptions to account for the differences in smoking behavior in the population. Based on surveys from the Surgeon General (241), we assume that the population of "current cigarette users"[14] is limited to 28 percent of children in the upper grades, 9th through 12th. A school population of 46.4 million students (232) would therefore consist of an average of 3.5 million smokers and 43 million nonsmokers. We also estimate that, on average, children spend about 12 percent of their total time throughout the year in-school, 75 percent at home, and 13 percent in other locations. Corresponding to these locations, EPA measurements indicate that, on average, radon exposures *in-school, home,* and *other locations* are 0.8 pCi/L, 1.25 pCi/L, and 1.0 pCi/L, respectively. It must be stressed that exposures differ widely, with a broad distribution of varying exposure patterns, some more, some less than these average exposures.

Based on these figures, OTA estimated the risks of lung cancer from the average levels in these three areas of likely radon exposure. OTA calculates that the risks from one year's exposure to average in-school radon concentrations result in 64 lung cancers, though these cancers are not likely to appear for decades. About 35 of these cancers will be among smokers and 29 among nonsmokers. These risks are smaller than average risks from one year's exposure at home, which might lead to about 629 lung cancers, again decades later—286 lung cancers among nonsmokers and 340 among smokers. School children's exposures to average radon levels in other locations over a year's time might lead to an estimated 87 total cancers. **Thus, in-school radon exposures contribute to about 8 percent of the cancers due to average one year exposures among school children, which, given the large uncertainty of these estimates on a time-weighted basis, is roughly equivalent to the contribution of radon from other exposures.** These numbers for lung cancers are in addition to the average estimate of 15,000 lung cancers each year from radon exposure.

Estimates for lung cancer generally consider lifetime exposures to radon since its effects are cumulative. EPA and DHHS (253) report risks from exposures ranging between 0.4 and 20 pCi/L, and an analysis shown in the appendix examines the lifetime contribution of risk from various combinations of in-school and residential exposures. The combination of attending a school at high radon levels and living in a house with low levels is expected to be unusual. As observed on table 4-10, schoolrooms with higher levels are more likely to be found in areas where the homes also have high levels. **These calculations and considerations lead OTA to the conclusion that the majority of in-school exposures will have little effect on cumulative exposures.** Furthermore, given the 98.5 percent of all schoolrooms (based on long-term measures) with radon at concentrations below 4 pCi/L and the movement of students from room to room and school to school, it is unlikely that in-school exposures will result in substantial contributions to cumulative exposures.

Whether the numerical projections of risk that results from non-occupational radon exposures are accurate may never be known. The contribution of residential radon exposures to lung cancer risk is far from settled (2,33,85,103,118,120,192,

[14] The DHHS (241) defined a "current cigarette user" as a person who smoked cigarettes on one or more of the 30 days preceding the survey.

230), and it has not been possible to design a study that could verify or falsify the risk estimates for lung cancer deaths from indoor exposures. Although some studies of indoor radon and cancer have found associations, others have not, and, because of the small expected increases in lung cancer from residential exposures, it may be impossible to ever know for certain whether such exposures caused an increase in cancer (119,172). Since in-school exposures are a small fraction of total exposures, it will also be impossible to ever know whether in-school exposures to radon have caused lung cancers or whether reducing those exposures had any effect on cancer rates because of the short exposure times in schools.

As has often been pointed out (247), EPA's calculated risk from in-home radon exposure is far higher than most of the risks it attempts to regulate. Many risks are regulated to prevent one cancer per 100,000 people or one cancer per 1,000,000 people. When looked at from that perspective, some cancer risks from in-school exposures seem large. Nevertheless, they pale in comparison to total risks from lifetime radon exposure and are about the same as from in-home radon exposure.

Only in what appear to be exceptional circumstances do in-school exposures make significant contributions to lifelong radon exposures, which, at certain levels, are unavoidable. In summary, the intensity of radon exposures in schools, on average, is lower than from residential exposures, and the duration of in-school exposures is far less. The risks from in-school radon are about the same as those from other environments in which children spend time.

Other Air Contaminants

The presence of other air contaminants poses possible hazards in schools. OTA examined the available illness, exposure, and health effects data for environmental tobacco smoke, volatile (and semivolatile) organic compounds, combustion products, and biological contaminants. In each category, ample health effects data suggest that exposure to particular agents can lead to adverse health effects, especially in school-aged children. Nevertheless, little evidence exists to demonstrate that school children are being exposed, if at all, to dangerous levels of agents. The available data come from case studies of a single school or a few schools with specific problems. Hence, inadequate data are available to conduct a quantitative assessment of the health risks in schools from these indoor air contaminants.

Environmental Tobacco Smoke

Long before the release of the first Surgeon General's report on smoking in 1964, the adverse health effects of tobacco on smokers, chewers, and other direct users were well established. More recently, the effect of tobacco smoke on nonsmokers has attracted much attention, and recent reviews paint environmental tobacco smoke (ETS) as one of the most widespread and harmful of pollutants found indoors (73,148,193,256). In 1992, EPA released an influential risk assessment of environmental tobacco smoke (256).

Cigarette smoke is a complex mixture of particles and chemicals. It contains more than 4,700 chemical compounds, including: carbon monoxide, nicotine, carcinogenic tars, sulfur dioxide, ammonia, nitrogen oxides, vinyl chloride, hydrogen cyanide, radionuclides, and arsenic; so far, scientists have identified 43 possibly carcinogenic compounds in this mixture (73,256).

Sources of ETS—smokers—are present in schools. Different surveys have collected data indicating that 70 percent of high school students had tried smoking, even one or two puffs, and 28 percent had smoked one or more cigarettes on one or more of the 30 days preceding the survey (241), and between 9 and 12 percent of staff in 26 surveyed schools smoked (169). Whatever the number of smokers, their contribution to ETS in schools is decreasing as more schools formally restrict smoking in school and on school grounds (not all restrictions extend to school grounds). Smoking restrictions have been put in place at the federal, state, and local government levels. In a 1989 survey by the Association of State and

Territorial Health Officers (239), 39 states were found to have regulations that restricted tobacco use in schools. Twenty-seven states banned smoking for students; eight states banned smoking for both students and staff. Since 1990, Wisconsin has prohibited all smoking on school premises. Local ordinances are increasing, and at least 297 cities and counties restrict workplace smoking. The policy in many states and school districts is to allow staff to smoke in designated areas, which are often the only lounge areas available to them. The National School Boards Association (153) conducted a random survey of smoking policies in 2,000 of the more than 15,000 public school districts in the United States. Of the 1,310 districts responding, 17 percent totally banned smoking—both on school grounds and at school functions. On March 31, 1994, with the Educate America Act, President Clinton signed into law a provision that required all federally funded programs serving children under 18 years of age, such as Head Start, to be smoke free.

EPA attempted to estimate the impact of ETS, most of which is from in-home exposures, on childhood asthma and lower respiratory tract infections in young children. EPA attributed from 8,000 to 26,000 new cases of asthma in previously unsymptomatic children under 18 years of age to environmental tobacco smoke from mothers who smoke at least 10 cigarettes a day. In addition, EPA considers exposure to parental smoking to be a major aggravating factor in approximately 10 percent, or 200,000, of asthmatic children. However, in-school contributions were not addressed.

Not only does ETS contribute to respiratory dysfunction, but EPA also concluded that ETS is a Group A carcinogen. EPA classifies agents as such when there is sufficient evidence from epidemiological studies to support a causal association between exposure to the agent and cancer. Tobacco industry consultants and scientists (66) criticized EPA's ETS risk assessment for lung cancer for an inappropriate use of statistical methodologies to establish the significance of the available data. Regardless of whether or not ETS is carcinogenic, no reliable data exist on the exposure of students to ETS in schools. Without exposure data, quantitative estimates of risk cannot be made for the school environment despite the extensive literature on the biological effects of ETS on children.

Although there are no data on exposures in schools, certain conclusions can be drawn. In-school exposures are certainly lower than exposures to children who live with smoking adults; they are decreasing further as school districts restrict smoking; and they are zero in many schools.

Volatile Organic Compounds

Volatile organic compounds (VOCs) are a broad class of carbon-containing chemicals that evaporate readily at room temperature and enter the air as gases. They are found in homes, workplaces, outdoor air, and schools, and many are commonly used solvents or carriers for other chemical agents. Hundreds of VOCs with unknown health effects have been detected in indoor air. In fact, some studies have shown that certain VOCs may be found in indoor air at concentrations five to 10 times higher than outdoors (113,265).

At the higher exposure levels in some workplaces, many VOCs have been linked to adverse health effects, including eye and throat irritation, breathing difficulty, headaches, dizziness, and inability to concentrate; a few VOCs are carcinogenic. VOCs may be given off in school indoor air by building materials, cleaning solvents, furnishings, pesticides, dry-cleaned clothes, cosmetics, paint, and air fresheners. Some emissions have been reduced by reformulation of products; for instance, adhesives have been devised that emit fewer VOCs and these are now recommended for school use (125).

OTA found no systematic examination of VOC levels in schools. There are a few, isolated case studies. In one, NIOSH investigators surveyed two schools in which occupants complained of odor and health symptoms following the use of organic solvents to remove floor tiles (96). The total VOC concentrations arising from this use were not excessive relative to occupational guidelines. Yet the odor persisted for long periods, and the school occupants, who were not identified in the report as children or adults, perceived that a health risk existed.

Combustion Products

Combustion products arise from the burning of natural gas or kerosene for heating and cooking, from conducting laboratory experiments, and as exhaust from buses and cars. In this respect, as in many others, school environments resemble home environments. During the combustion process a number of gases are created and released, including nitrogen dioxide (NO_2), carbon monoxide (CO), carbon dioxide (CO_2), nitric oxide (NO), and water vapor. Because of their toxicity, NO_2 and CO are of most concern.

Exposures to levels of NO_2 greater than 5,000 ppb in air have been associated with respiratory effects that increase in severity with exposure levels and duration (191,194). Pilotto and Douglas (175) found a relationship between indoor nitrogen dioxide levels and childhood respiratory illness in the studies they examined. NIOSH recommends that workplace exposures to NO_2 not exceed 1,000 ppb, but there are no reports of such levels in U.S. schools (235). Levels ranging from 10 to 2,900 ppb were reported, however, in a survey of 600 classrooms in New South Wales, Australia, where schools rely on unflued gas heating in winter (175).

Carbon monoxide, a product of incomplete combustion, is a major pollutant in automobile exhaust and is also formed during combustion in furnaces, heaters, and engines. Carbon monoxide binds easily to the oxygen carrier hemoglobin, disrupts delivery of oxygen to body tissues, and causes "flu-like" symptoms of nausea, dizziness, fatigue, and headache, as well as behavioral changes and difficulty in thinking and concentrating. Very high concentrations can cause death, and an estimated 1,000 people die each year from exposure to CO (31).

Combustion byproducts are not a problem in schools that have properly ventilated heating systems. Conversely, schools with poorly installed or poorly maintained equipment can have high levels of combustion products, and certain specialized heating situations are known to cause problems. Students who play ice hockey and participate in other sports in arena settings where combustion engines are used can be exposed to high levels of combustion products. Several reports in the northeastern United States have documented teams of school children becoming ill from highly elevated levels of CO and NO_2 in indoor sports arenas (81,105).

Biological Contaminants

A diverse array of non-infectious biological materials may be present in indoor school air (infectious diseases are considered later in this chapter). Non-infectious biological contaminants in indoor air include insect fragments and droppings, animal and human dander, and various animal and plant materials—including some molds and fungi (176). While most molds and fungi in indoor air probably enter from the outside, the organisms grow and reproduce within some problem buildings.

Regular maintenance of the ventilation and filtration system is necessary for the control of biological materials. Reducing relative humidity can be important in keeping fungal spores from proliferating and in reducing the level of dust mites (158), but moisture and spore nutrients are always present in some heating and air conditioning systems. Moisture is also a problem because buildings can get wet in many ways, and flat-roofed schools are especially prone to leaks. In such cases, wet carpets probably constitute one of the greatest problems in schools, but any wet material will allow the growth of indoor microbial agents. The presence of mildew or mold is unacceptable, and ordinary housekeeping requires that any growth be removed immediately upon being observed. Chemical agents can be used to kill the organisms and cleaners to remove minerals that may serve as nutrients (137). Disinfecting the water in the cooling system can effectively control the spread of living organisms such as bacteria in buildings (195).

OTA could not find studies demonstrating general problems with biological contaminants in school, beyond infectious diseases. Yet their presence can elicit allergic responses (176), which is an exaggerated immune response to substances. These conditions are not necessarily affected by the school environment, but they can be triggered by a variety of stimuli that can exist in schools with IAQ problems, such as irritants (especially ETS) and allergens (e.g., pollen, dust, or insect parts) (176). OTA could not discern the contributions of school-borne allergens to these conditions from the available data.

SCHOOL LOCATION

Parents, teachers, and administrators often express concern about, and even fear of, hazards arising from the location of a school. Concerns and fears associated with location can come from the general environment, such as polluted air or water, or from placement of the school on or near hazardous waste sites or close to power transmission lines. Information regarding the risks associated with those exposures are discussed below. However, insufficient data exist to assess these risks quantitatively or even qualitatively.

Electromagnetic Fields

Metaphors such as "flammable" and "incendiary" are often used to describe the debate about whether long-term exposure to electromagnetic fields (EMF) from power lines and electrical devices increases the incidence of cancer or produces other adverse health effects.[15] The emergence of each new research study adds the proverbial fuel to the fire. Are electromagnetic fields from these sources associated with cancer? Scientific panels find the existing body of research inconclusive (149,164). School officials are hampered by the absence of scientific agreement, a dearth of legislative or regulatory guidance, and the prospect of mitigating an exposure when there is no consensus over what aspect— if any—of that exposure is biologically important. This uncertainty, coupled with the difficulty of mitigation, can leave administrators in a quandary: when offered an EMF profile of their school free of charge by their local utility, only 5 percent of school officials in Maine agreed to have their school evaluated (46).

School is a likely battleground for the EMF debate because it is a focal point for the way a community treats its children. Concern has also been raised by articles in the popular press that have attributed childhood cancers to EMF exposure at school. Elevated EMF levels in schools have become a source of conflict among parents, school administrators, health departments, and utilities. In California, New Jersey, and New York, some school buildings and classrooms have been sealed off or converted to storage areas as a result of community pressure (200). In New York State, the wiring leading into some schools has been changed to reduce EMF levels (271). Power lines, while not necessarily the only or the most important source of EMF exposure, have become a potent symbol of environmental controversy.

Overshadowed by the polemics is a straightforward reason for studying the school environment: children, especially those in higher grades, spend significant time at school both during regular hours and in after school programs. In an average year, children spend 12 to 20 percent of their time at school (95,100). Even though most of their time is spent at home,[16] where EMF levels and potential health effects have been more thoroughly studied, the school does contribute to overall exposure.

Do some schools have elevated EMF levels? Does exposure to EMF in schools increase the

[15] The focus of this section is concern about cancer risks from exposures to power lines and other sources with similar EMF characteristics. Some studies have reported other biological effects from these sources, such as changes in melatonin levels. EMF sources with different characteristics—such as video display terminals and communications antennas—have also raised concerns in various school settings. There is so little information concerning these exposures and their effects, if any, on children that OTA is unable to draw a conclusion one way or the other on this issue.

[16] Children spend on average about 70 percent of their time during a year at home (96), where the mean magnetic field level is 0.9 milligauss (mG) and the median is 0.6 mG (276).

incidence of cancer? Neither question has been comprehensively or systematically studied. Only a few small-scale studies have been conducted in the school environment; these are discussed later in this section. Some of these studies suggest that EMF levels at certain schools are high enough to trigger concern, based on epidemiological studies of residential EMF levels associated with childhood cancer. Cancer clusters have been documented in schools near power lines, although a causal connection between the clusters and the power lines was not established (22,24).

The main purpose of this portion of the report is to identify and summarize the small body of research studies conducted in the school setting. Before doing so, this section acquaints the reader with electromagnetic fields and summarizes the controversy surrounding their health effects. It then discusses the myriad opportunities for EMF exposure in the school setting, how levels are measured, and some existing exposure policies. After a review of the case studies of schools near power lines and the research characterizing school EMF levels, this section concludes with a qualitative assessment of the risks from EMF exposure in schools (see box 4-5).

EMF Health Effects Research

Scientists don't know what aspects of EMF exposure—if any—define a biologically meaningful dose. Dose is most commonly characterized in terms of the strength of the field and the duration of exposure: a time-weighted average. Experience with chemicals and ionizing radiation leads to the rule of thumb that the higher the time-weighted average exposure, the greater is the expected effect. Some serious questions have been raised, though, about whether this paradigm holds for power frequency EMF. There are other ways of characterizing exposure, including how quickly or how often the field changes over time, the peak field strength, or the amount of time spent in the presence of a field whose strength exceeds some threshold level (box 4-6). However, it is not known whether any of these yields a more informative measure of dose.

Present-day power frequency EMF health effects research tends to focus on exposure to the magnetic component of the field. Indeed, in this context, the term EMF is sometimes used by the public and even some scientists to refer just to the magnetic field. This may be in part because many common objects—trees and buildings, for example—provide shielding from electric fields, while magnetic fields pass through most things without diminishing significantly in intensity. Because of attenuation, an external power frequency electric field induces a very much (over a million times) smaller electric field inside the body (165). In contrast, the human body does not appreciably attenuate a power frequency magnetic field.

Because there is no significant transfer of energy from power frequency fields to biological systems, many scientists did not think at first that they could affect human health (227). But newer experimental research, stimulated in part by the epidemiological studies discussed below, has found that electromagnetic fields can have biological effects in animals and in the test tube. Animal research has shown that EMF exposure may affect behavior and learning, blood and immune system chemistry, reproduction, and hormone levels.[17] Research on EMF suppression of the hormone melatonin has aroused scientific interest because of a possible link to one form of cancer: melatonin plays a role in modulating the immune system and in suppressing estrogen, which has a role in breast cancer induction (39). The effects of EMF exposure on experimental animals do not result from breaking chemical bonds or heating tissue, and the interaction mechanism(s) are not understood. Searching for mechanisms that might explain the epidemiological and experimental findings is one of the challenges facing scientists.

Concerns about the effects of EMF exposure surfaced in the 1960s, but the first examination

[17] Recent reviews of animal and cellular-level studies include Hendee and Boteler (82).

BOX 4-5: What Is EMF?

Electromagnetic fields are everywhere. They are created by electrical charges. If the charges are stationary, only an electric field is produced; magnetic fields are produced by electrical charges in motion. Fields whose direction and magnitude are constant over time are called *static*. Static and nearly static electric and magnetic fields occur naturally: they have always been a part of the environment and they are present in all living things. Alternating fields are those whose direction and magnitude oscillate over time. They are produced primarily during the generation, distribution, and consumption of electric power, although some very low-intensity natural fields also exist.

The intensity or strength of a magnetic field depends on the current of its source, whereas electric field intensity is related to the voltage of the source. *Current* is the measure of the rate at which electrical charges flow through a circuit; *voltage* is the measure of the potential energy that makes charges flow through the circuit. Both electric and magnetic fields diminish rapidly in intensity as distance from the source increases. Thus, a relatively low-intensity nearby source—a clock radio next to a bed, for example—may contribute more to the EMF exposure of a sleeping child than a transmission line visible in the distance from the bedroom window. Fields from two or more sources may add together or cancel one another out, depending on their locations in time and space.

Transmission lines, transformer substations, distribution lines, electrical wiring, and appliances are common sources of electromagnetic fields (table 4-14). Transmission lines are the electrical wires held up by tall metal towers. They are used to send high-voltage electricity over long distances. Transformer substations "step-down" electricity from transmission lines so it can be conducted to buildings and residences via smaller, distribution lines. Electrical wires of any type used to transmit electric power give rise to fields that oscillate in the extremely low-frequency range. The power frequency in the United States is 60 hertz, while in Europe and some other places it is 50 hertz (the unit hertz denotes the number of times the current alternates, or cycles, per second). The term "power frequency EMF" refers to these frequencies. Other electromagnetic phenomena such as light and radio transmission exist at much higher frequencies (thousands or millions of hertz). Electrical devices such as video display terminals generate electromagnetic fields at both power frequencies and higher frequencies. Power frequency magnetic field strength—technically speaking, magnetic flux density—is commonly measured in units of milligauss (mG) or microtesla (μT). One milligauss equals one-tenth microtesla (1 mG = 0.1 μT). Electric field strength is usually reported in volts per meter.

SOURCE: Office of Technology Assessment, 1995.

of general population magnetic field exposures came in 1979 with the publication of an epidemiological study that found a statistical association between residential wire codes and childhood cancer (268). This study examined 344 children in the Denver area who died of cancer and compared them to an equal number of children who were cancer free (controls), matched for age. The homes of the children were classified by wiring code, which took into account the type and number of outside electrical distribution lines and their distance from the home. The *high-current configuration* wiring code was assumed to carry a stronger magnetic field, although the actual field strength was not measured. Children in the high-current configuration homes were found to have a two- to threefold higher incidence of cancer than controls—in other words, roughly double the background incidence.

Because of potential problems with the design and conduct of the Wertheimer and Leeper study, corroboration of its findings was subsequently sought by other researchers. Studies conducted by Fulton et al. (59) and Myers et al. (146) failed to find an association between higher estimated residential magnetic field levels and increased childhood cancer incidence for study populations

BOX 4-6: Magnetic Field Measurements and Estimates

There are many types of magnetic field measurement and estimation techniques, each of which has advantages and disadvantages. With disagreement about which techniques best characterize exposure, researchers tend to use a combination of any of the following: wiring codes, personal exposure meters, survey measurements, and theoretical estimates of field strength. These techniques are discussed below.

The use of wiring codes to estimate magnetic field exposures was developed by Wertheimer and Leeper (1979) and subsequently refined by several researchers. In this method, homes are classified in different exposure level categories after visual inspection of the types and number of overhead wires near the residence. The advantages of wiring codes are that they are usually stable over time (and thus may yield information about historic exposures) and do not require entry into the residence. This technique does not, however, capture variations in exposures generated by indoor sources or variation due to distance gradients from the external source(s). Further, wiring codes were developed for examining exposures in single-family residences, and their applicability to other structures—including schools—is problematic.

Personal exposure meters are worn by an adult or a child, usually for a fixed period such as 24 hours. The meter calculates an individual's time-weighted average exposure, the average magnetic field strength over a period of time. However, the device can be cumbersome, and cost and availability limit its use.

Survey measurements are typically taken by a meter placed in a fixed location for a specified period. These measurements can be of very short duration ("spot") or long enough to characterize the average level (24 hours, for example). To distinguish external versus internal contributions to the field at an indoor fixed location, measurements are sometimes taken under so-called low- and high-power conditions. Under low-power conditions, lights and appliances are turned off in order to approximate the contribution from magnetic fields external to the site (household wiring continues to carry current and some appliances remain powered even when turned off, so internal sources are still present). Under high-power conditions, lights and appliances are turned on to approximate their contribution to the field. These types of field measurements are relatively easy to take but cannot capture seasonal, temporal, and spatial variability in field strength.

Theoretical estimates of field strength are sometimes used to reconstruct exposures that occurred in the past. Historic field strengths are important because cancers may take a long time to develop and present-day levels may not accurately reflect past levels. For transmission lines, historic field strengths can be estimated by using records of system voltage, current, and wiring geometry. This is far more difficult for sources such as transformers because current loadings are not typically recorded. Field strength calculations can also be useful in estimating present-day magnetic field levels near lines, although the role of grounding currents makes the estimation of magnetic fields from distribution lines more problematic. This method is not, however, fully accepted by the scientific community and remains controversial.

SOURCE: W. Kaune, "Assessing Human Exposure to Power-Frequency Electric and Magnetic Fields," *Environmental Health Perspectives* 101:121–132. 1993.

in Rhode Island and England, respectively. Tomenius (221), however, found that there were more overhead power lines near the homes of cancer cases than controls in a study population of children in Sweden. Increased cancer incidence was also noted for children in homes where a spot measurement (taken at the front door) of the magnetic field intensity exceeded 3 mG.

Studies in the Denver area (198) and in Los Angeles County (116) also supported the association between wiring code and childhood cancer incidence. In the Savitz study, children living near lines coded as *very high* or *high* current configuration had a 1.5 times greater risk of cancer than those living near lines coded as *low, very low*, or *buried wire.*[18] London reported that children living near the highest-current configuration lines had a 2.2 times increased risk of leukemia. In both of these studies, statistically significant associations were found between wiring codes and childhood cancer but not between measured magnetic field intensities and cancer. These findings have puzzled researchers because intuition suggests that measurements should characterize exposures better than indirect estimates. There are several competing explanations for the outcomes observed. Some have postulated that measurements made for the studies (spot measurements by Savitz; both spot and 24-hour measurements by London) were too variable over time and not indicative of long-term past or present exposure. Others speculate that an aspect of EMF exposure captured by wiring codes but not average field measurements is responsible for the association, or that the wiring code is statistically associated with some as yet unidentified risk factor related to cancer but not to EMF. Finally, there may be no association between EMF exposure and childhood cancer and the mix of positive and negative results may be due to chance.

Three Scandinavian studies of children living near power lines have attracted a great deal of attention. Although all support, to varying degrees, an association between magnetic field exposure and increased cancer incidence, each found an association with a different type of cancer and failed to find associations with the types of cancer implicated in the other studies. In the first study, published in 1992, Feychting and Ahlbom investigated 142 cases of childhood cancer identified from among 500,000 residents living within about 1,000 feet of 220- and 400-kilovolt (kV) transmission lines in Sweden during 1960–85. One of their most important findings was a dose-response relationship, one of the cardinal means of helping to establish cause-and-effect (although determining dose from EMF exposure is problematic). Children living in areas where the calculated magnetic field levels were higher than 2 mG had a 2.7 times greater risk of leukemia than controls. Where the magnetic fields were higher than 3 mG, the risk of leukemia increased to 3.8 times the controls. Control children were matched for gender, age, time of diagnosis, and region of residence in Sweden. Magnetic fields were calculated on the basis of distance from a line and historical data on power line configuration and load. There was no evidence of an association with brain cancer or with all childhood cancers.

In the second study, which was similar in design to the Swedish study, Danish researchers found a fivefold relative risk of childhood cancer among children with previous estimated exposure greater than 4 mG to power lines and other distribution equipment (166). When the data were stratified by type of cancer, there was an increased risk for lymphoma (at levels higher than 1 mG), but not for leukemia or brain cancer. In the third study, Finnish researchers did not find a statistically significant increase in leukemia or lymphoma at any calculated field intensity but did find an excess of brain tumors in boys living in areas with calculated magnetic fields of 2 mG or higher (261). When the authors of these three studies combined their data, they concluded that there was a statistically significant association between power line EMF levels and leukemia, but not brain tumors or lymphoma (1).

Similar, but not identical, conclusions were reached in a meta-analysis of almost all extant studies of childhood cancer in relation to power lines (267). Researchers combined and analyzed 13 previously published epidemiological studies (including the three Scandinavian studies), some of which had contradictory results. Their analysis

[18] A reanalysis of the data using a modified wiring code found statistically significant (95 percent confidence interval) higher risks for all cancers, leukemia, and brain cancer (197).

found statistically significant elevated risks of childhood leukemia and brain tumors, but not lymphomas.

Some points should be kept in mind when considering the results presented in this section. Epidemiological studies that identify relatively modest associations cannot prove that a particular exposure is or is not the cause of a health problem. Instead, they are a piece of a puzzle that must be fit together with information from other sources such as animal and cellular-level studies before conclusions can be drawn. All of the epidemiological studies cited above have been criticized on various grounds, and more research is needed to substantiate or refute their findings.[19] More generally, it has been suggested that the tools of epidemiology are simply not powerful enough to establish an effect when increases in risk are on the order of a factor of two.[20]

It should also be pointed out that childhood cancer is rare, and childhood leukemia rarer still. In 1987, the incidence of childhood cancer was 13.7 per 100,000 children and the incidence of leukemia was 4.1 per 100,000 (236). Historical incidence trends are difficult to determine because nationwide surveillance systems have been in existence only since 1973. Brain tumors are also quite rare, although some reports were found in studies with occupational exposures (54). When examining the incidence of rare events in a population, it is important to remember that even small absolute differences in the number of cases may affect whether a result is statistically significant or not.

Opportunities for Exposure in Schools

The school environment offers numerous opportunities for exposure to power frequency electromagnetic fields. Because there is a wide range of magnetic field levels associated with the sources commonly found outside and inside schools, it is not possible to characterize the "average" or "typical" levels associated with these sources.

The most common external sources of electromagnetic fields in schools are likely to be transmission lines, distribution lines, and transformer substations. Common internal sources are the school's electrical wiring, transformers, ground wiring, and devices such as video display terminals, overhead projectors, and other electrical equipment (91,210). The magnetic field produced by electrical devices drops off quickly and is usually negligible 3 to 4 feet away. That is why fluorescent lights mounted on the ceiling may be an insignificant source of magnetic field exposure at floor level while the same lights in study cubicles or under cabinets may be a more important source.[21] Box 4-6 discusses the various means used to measure or estimate magnetic field levels.

Regulations Pertaining to Schools

There are no federal standards for power frequency EMF exposure. Legislation was introduced in 1993 that would have prohibited the siting of new schools and day care centers on properties where magnetic field levels exceed 2 mG.[22] Several states limit electric field strength levels at the edge of transmission line rights of way, and others have legislation mandating research, education, and public participation in siting decisions (132). Florida sets a limit on magnetic field strength: 150 to 250 mG at the edge of the power line right of way, depending on the type of line.

Some states, localities, and schools have adopted EMF exposure policies. For example, New York's Public Service Commission, the state licensing body for utilities, prohibits newly sited transmission lines from exceeding magnetic

[19] Sagan (188), Savitz (196), and Tenforde (219) have all recently reviewed this literature. Jones et al. (92) addresses the issue of other factors that might help explain the studies' results.

[20] Dr. Dimitrious Trichopoulos, Chair, Department of Epidemiology, Harvard School of Public Health, quoted in Taubes (217).

[21] Fluorescent lights hung from the ceiling on one floor can be the source of magnetic fields for individuals situated on the floor above (55).

[22] The Children's Electromagnetic Field Risk Reduction Act of 1993 (H.R. 1494), introduced by Representative George Miller.

field strengths of 200 mG at the edge of a right of way. The Montecito Union School in California has a policy of removing children from sites within the school where prolonged exposures to magnetic fields exceed 2.5 mG (189). This school policy relies on the widely cited strategy of "prudent avoidance" that was first articulated in a 1989 OTA report (227). Prudent avoidance, in brief, is defined as the policy of eliminating or minimizing an exposure when this can be done for modest investments of money and effort. It has been proposed as a means of dealing with an uncertain risk such as EMF exposure until the science regarding it becomes more certain. Steps might include moving desks or relocating play areas away from places where high field strengths are present. More expensive and inconvenient steps might include rerouting or redesigning electrical systems.

Studies in Schools

OTA was able to identify only a few studies of EMF levels at schools and even fewer studies dealing with the health effects of school EMF exposure. Most research has focused on children's residential exposures. The studies described in this section are from the peer-reviewed literature or are case studies conducted by a health department or utility. For our purposes, the studies are segregated into two categories: health effects studies and exposure studies. Because the complexity of study design is great and the findings are diverse, a summary table (table 4-11) is provided to enable the reader to contrast and compare studies. Of the 10 studies discussed below, three were still in progress when this report was completed.

Health Effects Studies

The only available studies that examine the health effects of EMF exposure at schools are cluster studies. A cluster study is a type of epidemiological study typically undertaken by a health department when it receives information about an unusual aggregation of health events—real or perceived—in a community. Cluster studies are usually intended as a stepping stone to generate research hypotheses for a standard epidemiology study. They can rarely be used alone to reveal an association between an exposure and a health outcome (25,159,236).

Montecito Union School. The California Department of Health Services (CDHS) was asked to investigate an suspected leukemia cluster in children residing in Montecito, California, a small community near Santa Barbara. Five of the seven children with cancer attended Montecito Union School, which is bordered by 66-kV power lines. Parents asked that the state include EMF as a potential factor in the cancer cluster investigation (189).

In its initial report, the California Department of Health Services (22) confirmed the presence of a leukemia and lymphoma cluster: the seven cases were about five times higher than the number expected in a community the size of Montecito. In an attempt to explain the cluster, CDHS researchers took soil and drinking water samples as well as magnetic field measurements around homes and the school. They concluded that none of the environmental exposures measured could explain the cancer cluster. This conclusion met with community skepticism because of concerns about the state's EMF measurements. The school board appointed an EMF task force, which requested an independent study of EMF exposure with design input from the community.

The second magnetic field profile was conducted by Enertech Consultants and incorporated into a later report issued by CDHS (23). This evaluation, using a variety of measurements, had results similar to the earlier one. While most classrooms and playgrounds were found to have relatively low magnetic fields (0.5–1.0 mG), some areas did have elevated fields: playgrounds near a power line; outdoor areas where underground and overhead power lines coincided; locations near switch boxes and transformers; and some areas and corners of classrooms, especially those near circuit breaker panels. Even before the second set of measurements was taken, the school board adopted an interim policy—recommended by the EMF task force—to

TABLE 4-11: Summary of School Studies of EMF Exposure or Field Intensities

		Magnetic Field Measurements					
Study	Number of Schools	Near Transmission Lines	Outside School	Inside School	Personal Monitors	Theoretical Calculations	Findings/Comments
Montecito Union School (CA)	1			X			Leukemia/lymphoma cluster in children; some elevated fields.
Slater Elementary School (CA)	1	X	X	X			Excess cancers in staff working near power lines; fields sometimes >2 mG.
U. Toronto Childhood Leukemia	400	?		X	X		In progress when this report was completed.
NCI	19		X	X	X		School exposures lower than home; very low correlation between measurements taken at different sites inside school.
Enertech	17		X		X		Mean personal exposures 1.2–3.8 mG; very low correlation between measurements taken at different times
EPRI Nonresidential Pilot Study	4	X	X	X			Mean field intensity inside ~1 mG, median ~0.5 mG; highly variable over time.
New York State Survey	116					X	Peak fields due to transmission lines >2 mG at building for 22 schools.
New Jersey Survey	49	X	X			X	Measured field intensities of 0.2–47.3 mG.
Maine Survey	37		X	X			Final report not yet available when this report was completed.
Swedish National Electric Safety Board	?	X				X	In progress when this report was completed.

SOURCE: Office of Technology Assessment, 1994.

remove children from areas where fields exceeded 2.5 mG for prolonged periods of time. This policy remained in effect after the release of the second report (189).

Slater Elementary School. The California Department of Health Services was also called in to investigate an alleged cancer cluster among teachers and staff at Slater Elementary School in Fresno, California. Teachers claimed that magnetic fields from nearby power lines had caused the cancers. Those with cancer were working all or some of the time in classrooms and administrative areas closest to the 115- and 230-kV transmission lines. In its report, CDHS confirmed 13 cancers among teachers and staff, when about seven were expected for the entire campus on the basis of cancer incidence rates in the general population (24). Even though the observed number was almost double that expected, the excess was not statistically significant unless a subset of cases was evaluated. When the analysis was restricted to cases among the adult staff working in three of the school's buildings closest to transmission lines, the observed number was four times that expected and did reach statistical significance. The cases included breast, uterine, ovarian, and brain cancers—some of which were considered by the investigators to be biologically and etiologically related. After the report was issued, two additional cancer cases were identified (63).[23] Among students, there were seven reported cases of invasive cancer, an amount lower than the expected number of 27.

Magnetic field readings at the school proved highly contentious. Six different sets of school magnetic fields measurements were taken by the utility, CDHS, teachers, and consultants invited by parents. After discussing the different measurements, CDHS concluded that magnetic fields from the power lines occasionally rose above 2 mG in parts of the school closest to the line. The overall conclusion of the cluster study was that chance was a plausible explanation for the cancer cases.

University of Toronto childhood leukemia study. A large case-control study of childhood leukemia is being conducted in the greater Toronto, Ontario, area by the University of Toronto (134). The significance of this study is that it will be the first large epidemiological study to measure magnetic field exposures both at home and at school. Two hundred children diagnosed with leukemia and 400 controls will be studied. Personal exposure meters and field measurements taken at the children's homes and the schools that they attend will be used to characterize exposures. The selection of schools is not intended to be representative since it depends solely on which schools are attended by case and control children. Results from this study will become available sometime in 1996.

Exposure Studies and Surveys

National Cancer Institute dosimetry study. In 1994, the National Cancer Institute (NCI) published a study of 29 children's exposures to magnetic fields at home and outside the home, including schools and day care centers (95). Of the studies described in this subsection, this was the only one published in a peer-reviewed journal. The aim of the NCI study was to guide the development of an exposure protocol for a much larger study assessing the relationship between childhood leukemia and exposures to power frequency magnetic fields.

Researchers found a very strong correlation between readings from a personal exposure meter worn by the children and area magnetic field measurements taken at home. School area measurements, however, bore little relationship to overall personal exposure. The school magnetic field area measurements (means ranging from 0.5 to 1.2 mG) were on average lower than home area measurements. School measurements were taken in the children's primary classroom and other locations inside and outside the school

[23] The finding of new cases after a report is released frequently occurs in cluster investigations because resource limitations preclude researchers from tracking down all cases of cancer in a potential study population.

where they were likely to spend more than one hour per week. Within the school, levels were quite variable, resulting in low correlations between measurements taken at different sites in the school. The highest readings in the school were found in a category called "other areas," which included the computer rooms, art rooms, and music rooms.

This study was not designed to be a comprehensive or nationally representative assessment of school magnetic fields. According to its authors, the finding of relatively low magnetic fields at the schools could be a result of the small sample size (19 schools and day care centers) or an artifact of the time of year and the small geographic area over which the measurements were made (95).

Enertech study. The Electric Power Research Institute (EPRI) sponsored a pilot study of both home and school magnetic field levels and personal exposure, which was conducted by Enertech Consultants (94). The purpose of this study was to develop improved methods of assessing residential and school exposures and to generate hypotheses for further research. Investigators compared different types of measurements taken six months apart. They focused on children living in 35 homes representing a range of electrical current configurations. Residential exposures, which occupied most of their analysis, are not described here. Measurements were also taken at the 17 schools and day care centers attended by the children whose homes were being studied. Neither the homes selected nor the schools attended were meant to be representative samples. Two types of measurements were taken at each school: personal exposure meters worn by the children and field measurements taken outside the school closest to the rooms most frequently used by students in the same grade as the study subjects. (The process of gaining permission to enter the school was so cumbersome that investigators restricted their measurements to outside the building.)

Measurements of personal exposure taken six months apart indicated that children were exposed to magnetic fields at school with means ranging from 1.2 to 3.8 mG. There was little correlation between magnetic field exposure levels taken at separate school visits. The measurements taken outside showed most schools to be clustered below 1 mG, with another cluster near 5 mG.[24]

Pilot study of nonresidential magnetic fields. Under an EPRI contract, a study was conducted to characterize magnetic field levels in office buildings, schools, and other settings distinct from the residential setting (91). Its purpose was to develop measurement techniques in preparation for larger studies of exposure in these settings. The evaluated sites were not meant to be nationally representative. Four schools in different regions of the country were included in the study, each of which was located within 500 feet of a 115- or 230-kV transmission line. A variety of field measurements was taken inside and outside the schools. In all four schools, the magnetic fields produced by the transmission line attenuated to less than 1 mG within the school, a finding similar to that of Harvey (78) and Peralta et al. (171). Inside the school, a measurement device was mounted on a wheel to produce a three-dimensional map of magnetic fields within the building. The spatial average magnetic field inside the schools was 1.06 mG, with a standard deviation of 2.05 mG. The median field strength was lower (0.47 mG), which suggested that the average was influenced by a small number of high measurements. Measurements from meters left for 24 hours at separate locations within the schools varied greatly over time, reflecting changes in field strength that typically result from turning electrical devices on and off.

New York State survey. At the request of New York Attorney General Robert Abrams, all eight utilities in New York State calculated magnetic field levels at schools in the state that are situated

[24] The higher cluster represented one school counted five times because it was attended by five of the study subjects.

near power lines (273). The utilities found that 116 of 6,473 schools (or 1.8 percent) were located within 100 feet of overhead power lines of 69 kV or higher. At these 116 schools, the utilities applied computer models to calculate peak and average magnetic fields, caused by transmission lines on the school property, closest to the power line, and closest to the school building. Ninety-nine had calculated peak fields of 2 mG or higher at some point on the school property. Twenty-two schools had calculated peak fields of 2 mG or higher at the point closest to the school building (table 4-12).

In the summary report of the utilities' findings, Wilson and Driscoll (273) acknowledge some methodological limitations: calculation of peak and average magnetic fields varied by utility, and two of the utilities used system load rather than circuit load to define the peak.[25] Despite these limitations, the State Attorney General viewed the survey as a means of informing the public and providing comprehensive and objective information to the schools. As a result of the survey, high magnetic field levels at several schools were reduced by taking relatively inexpensive steps (271).

TABLE 4-12: Calculated Magnetic Field Levels[a] at Schools in New York State

Magnetic field (mG)	At property line closest to source (number of schools)	At school building (number of schools)
< 1	9	79
1–2	8	15
2–3	7	2
3–5	14	7
5–10	22	5
10–20	27	2
> 20	29	6

[a] The eight utilities performing the calculations employed different methods to calculate magnetic field levels (see text).

SOURCE: Wilson and Driscoll, 1993.

New Jersey survey. All New Jersey utilities were asked by a commissioner of the New Jersey Board of Regulatory Commissioners (BRC) to conduct an EMF survey of all schools located within 100 feet of transmission lines. The purpose of the survey, begun in 1993, was to address growing public fears about EMF exposure and to establish baseline information.

The protocol guiding the four participating utilities called first for the identification of schools in their service areas that had buildings or play areas within 100 feet of the edge of a right of way. Once the schools meeting this criterion had been pinpointed, field measurements and calculated field strengths (using computer models of average and peak conditions) were required at four different locations outside the school. (If the school requested internal measurements, the utility would do so without reporting the data to the BRC.) The locations selected for measurement were: at the edge of the right of way closest to school property; at the edge of the school building nearest the right of way; at the center of the most commonly used outdoor student activity site; and near classrooms closest to transmission lines.

The utilities identified 49 schools within the state that had buildings or playgrounds near transmission lines. Magnetic field measurements ranged from 0.2 to 47.3 mG across the sites. No attempt was made to analyze the data as a whole or to quantify the number of schools with elevated readings, nor was any effort directed at comparing field measurements with those obtained from computer calculations of the load on the line. The final survey is a compilation of readings from all sites measured at each school.

Maine survey. In 1993, the three utilities serving the State of Maine offered all schools in the state the opportunity to have EMF field measurements taken at no charge. The utilities' action resulted

[25] System load refers to the total power supplied to all homes and industry. By using system load, some schools had peaks that, paradoxically, were less than the average field. The system load is thus not considered an accurate reflection of field strength at the school.

from an agreement among the state legislature, the Maine Department of Education, and the utilities after two bills that would have required testing did not receive legislative approval.

Thirty-seven of 700 schools contacted (5 percent) accepted the utilities' offer (46). When completed, the results of the surveys are to be reported back to each school and included in a final report to the legislature (263). The protocol governing the acquisition of data calls for outside and inside measurements taken while school is in session. Outside measurements include spot measurements taken on school grounds and around the building perimeter. If a transmission or distribution line is near, measurements are to be taken from under the power line to the farthest point of the school property. Inside measurements include a primary hall and, if requested, computer rooms, industrial arts room, kitchen, and service entrance. Preliminary findings—which may or may not be borne out in the final report—indicate that some of the highest school readings were found inside the school, irrespective of the presence of a nearby power line. Readings were especially high at service entrances, circuit breaker panels, boiler rooms, and vending machines (263).

Swedish National Electric Safety Board. An EMF survey of all schools near power lines has been undertaken by the Swedish National Electric Safety Board (233). A questionnaire was mailed to all area school administrators asking them to determine which of the schools in their jurisdiction were located within 300 meters (about 1,000 feet) of a power line. After seeking information about each school's distance from the line, power line characteristics, and other information, investigators calculated the field strengths at two-thirds of the maximum current for the power line. Thus far, investigators have estimated that approximately 10,000 children attend schools with magnetic fields calculated at 2 mG or higher (262). No measurements were taken inside the schools, thus precluding a determination of magnetic field levels from school wiring and other internal sources. A report of the findings was not yet available when this report was completed.

Assessment of Risks

There are some important differences in the research conducted to date on children's EMF exposures in school and at home. School exposures have not been characterized nearly as well as home exposures, although several efforts are under way to gather more information. Available data indicate schools have a greater number of EMF sources in and near them, and that EMF levels are correspondingly more variable. Because of this variability, no blanket statement can be made concerning whether children are exposed to lower or higher EMF levels at school than at home. Little is known about how school building characteristics such as age, location, and construction material may affect exposures, and as a result, it is not yet known whether existing measurements are representative of schools in general. Finally, it is possible that exposure estimation techniques developed for the home environment (such as wire codes) may not be applicable to schools. Further research is needed to fill these information gaps and provide a more informed basis for assessing risk and setting policy.

In comparison to other environmental risks described in this report, EMF is among the most uncertain. Although concerns have been raised that prolonged, elevated exposures may place individuals at increased risk, there is still no agreement among scientists as to whether power frequency EMF exposure presents a health risk. Those who believe a cancer risk exists are in general agreement that EMF does not cause cancer but instead acts as a promoter (that is, a cancer may be more likely to occur when an individual is exposed). The magnetic field component of power frequency EMF—which is generally unperturbed by buildings and walls, and penetrates the human body—is the typical focus of such concerns.

Electromagnetic fields are ubiquitous in the home and school. Each of these environments is replete with opportunities for exposure. Power frequency EMF exposure may come from sources inside buildings, such as electrical devices and wiring, or outside sources, such as transmission or distribution lines. The amount of such EMF exposure for any given child, whether in the home or the school, varies greatly: it depends on the number of sources, their intensity and configuration, their proximity to the child, and the amount of time the child spends in their presence. The impact of exposures at school and the school's contribution to an individual child's overall exposure are almost impossible to predict, even if the sources within both the school and the home are well characterized. Much depends on the child's dose (and no one knows exactly what measure of dose is most informative) and the child's response to the exposure.

Our knowledge of power frequency EMF exposure at school comes from a limited number of studies. What we do know is that levels at some schools equal or exceed those associated with increased incidence of certain forms of cancer in some residential studies. However, these residential studies of cancer address prolonged exposures (more than 12 hours per day), and their results may or may not be applicable to school exposures of equal magnitude. We also know that transmission lines are just one of many sources of exposure and not necessarily the primary source. So much of the school research has been driven by public concerns about transmission lines that other sources of exposure, particularly sources inside the school, have been neglected. Finally, we know that EMF levels vary from one school to another, vary among locations within a school, and vary over time at any one location. Much research is necessary not only to characterize school EMF exposures and exposure sources, but to determine the school's contribution to overall exposure.

Other Possible Location Hazards

Schools located on or near hazardous waste sites represent a potential hazard. Emissions from the site can result in the inhalation of hazardous materials. Agents contaminating the soil may be ingested or absorbed dermally following contact with the skin. Government agencies have received several complaints of illnesses or odors from schools located in proximity to hazardous waste sites. However, no data were available to document that the exposures have led to any verifiable illnesses.

Schools can be located in areas where noise poses a public health problem. Certain sites have noise levels that not only are uncomfortable but can also be disruptive to learning and even to student health. Schools situated in urban areas next to busy streets, construction sites, noisy markets, or next to loud industrial sites can experience unhealthy noise levels. A conference held in Nice, France, in July 1993 examined "Noise as a Public Health Problem" (260). Some of the health effects discussed at the conference included adverse effects on performance and behavior, sleep, communication, and hearing. A review of the current state of knowledge found the need for further research on the effects of noise on school-aged children, but some data suggest that noise stresses the autonomic nervous system and could be related to elevated blood pressure (203). One study presented at the conference described a project being undertaken in Germany to examine the psychological, cognitive, and quality-of-life effects on children of aircraft noise from the Munich International Airport (90). Despite the lack of substantive information on the health effects of noise, French officials described their schools as "much improved" through the use of soundproofed facades and the reduction of acoustic vibrations in classrooms and cafeterias (260).

INFECTIOUS DISEASE

Infections in school-aged children usually do not capture public attention to the same extent as violence or environmental hazards. The perception exists that infections are old problems, and either that the health care system is already able to address infectious conditions or that they are merely insoluble nuisances such as the "common cold" (104). In contrast to these beliefs and assumptions, however, infectious conditions represent a substantial cause of morbidity and mortality in school-aged children (201). On top of that, researchers and public health officials are raising additional concerns about infectious diseases. Infectious problems continue to occur, including new diseases such as HIV (human immunodeficiency virus) infection and streptococcal toxic shock syndrome, and new challenges, such as the emergence of drug-resistant bacteria and mycobacteria. Opportunities for prevention are becoming available with the development of new vaccines and the development and validation of strategies for behavior modification and risk reduction. Because of the high costs associated with infectious morbidity in school children and the availability of preventive measures that will likely prove highly cost-effective, attention on infectious diseases seems warranted from a public health perspective.

The problems discussed in this section are distinct from problems discussed earlier with biological contaminants of indoor air. Infectious diseases are spread mostly by student to student contact in the course of a normal school day and do not necessarily arise from inadequate maintenance of indoor air. Clearly, inadequate ventilation or overcrowding in schools may contribute to diseases such as influenza, and the airborne route is important for respiratory viral infections. Nonetheless, prevention or remediation of the diseases discussed here requires a public health approach (e.g., immunizations), rather than an engineering approach (e.g., improving the ventilation system).

Infections are traditionally classified by the pathogenic organism—bacterial, viral, and parasitic. However, the importance of infectious diseases in the school setting depends to a large extent on their mode of transmission. Person-to-person transmission is the primary mode of spread for bacterial, viral, mycobacterial (e.g., tuberculosis), and other respiratory infections, which are a major cause of morbidity in schools. These infections are frequently transmitted between and among children in school, particularly in the younger grades and in crowded settings. The importance of infections in schools is magnified because of the role that school children play in introducing these pathogens into their families, leading to disease in preschool-aged children and adults, often with more severe consequences.

Infections can be divided into two types on the basis of their occurrence in schools. Some occur with a high incidence on an endemic or seasonal basis; others occur less frequently and primarily as outbreaks. Certain "childhood diseases"—including mumps, measles, and chickenpox—are spread by the direct contact with an infected person, which often occurs in school. Vector-borne diseases are not spread within schools or through interaction with other children but commonly infect school-aged children and may be transmitted on school grounds, which can provide a habitat for disease vectors such as ticks infected with *Borrelia,* the bacterium responsible for Lyme disease. In contrast, foodborne and waterborne infections, including hepatitis A and enteric bacteria, generally occur in outbreaks, with transmission occurring from contaminated water or food.

Apart from endemic infections or outbreaks, bloodborne diseases such as HIV infection and hepatitis B are not generally transmitted in schools, but school-based interventions are a component of a prevention strategy. Interventions can include immunizations and school-based education programs on hygiene and high-risk behaviors.

Nature and Sources of Data

Substantial data are available from a variety of sources on many of the infectious conditions that occur in school-aged children. Sources of data include national surveys, disease-specific surveillance, focused epidemiological and laboratory research, and national or hospital-based databases. Nevertheless, OTA could not identify a national database on infectious disease in the school environment; as a result, OTA presents the available data on infectious disease in school-aged children. Initially, the studies described are the results of a national household survey and cases of notifiable diseases. The final section focuses on specific infectious diseases of most concern to this age population.

The terminology and approaches used by infectious disease epidemiologists, experts, and public health officials differ sharply from those described earlier in this chapter for environmental hazards. A review of the vast literature on pediatric medicine and childhood illness is not possible here and extends beyond the congressional request for this study. The interested reader should consult such established texts and reports as Benenson (13), Lederberg et al. (104), Evans and Brachman (50), Evans (49), and Mandell et al. (123).

The first step in the control of communicable disease is its rapid identification, followed by notification to the local health authority that the disease exists within the particular jurisdiction. Generally, a system of reporting functions in four stages (13). The first is the collection of the basic data in the local community where the disease occurs. The data are next assembled at the district or state level. The third stage is the aggregation of the information under national auspices. Although not relevant to this study, in the final stage a report is made for certain prescribed diseases by the national health authority to the World Health Organization. Administrative practices on the diseases to be reported and how they should be reported may vary greatly from one region to another because of different conditions and different disease frequencies.

In this report, OTA examines data developed for national use, either collected locally or from a national survey. The basic data sought at the local level are of two kinds: **Case reports** and **reports of epidemics**. Each local health authority conforms with regulations of a higher health authority, such as a state health agency or the Centers for Disease Control and Prevention (CDC), to determine what diseases are routinely reported, who is responsible for reporting, the nature of the report required, and the manner in which reports are forwarded to their superior jurisdiction. Physicians are required to report all notifiable illnesses (described below) that come to their attention; in addition, statutes or regulations of many localities require reporting by hospital, householder, or other persons with knowledge of the case. *Case reports* of a communicable disease provide minimal identifying data of the patient and the disease. *Collective reports* are the assembled number of cases occurring within a prescribed time and without individual identifying data. In addition to the requirements for individual case reports, any unusual or group expression of illness that may be of public concern is to be reported to the local health authority: a report of epidemics. An epidemic is the occurrence in a community or region of cases of an illness (or outbreak) clearly in excess of expectancy (13). The number of cases indicating presence of an epidemic will vary according to the infectious agent, size and type of population exposed, and previous experience.

In contrast to the passive reporting for the notifiable diseases, the NCHS National Health Interview Survey (NHIS) is a continuing nationwide survey of households (14). Each week personnel of the Bureau of the Census interview a sample of the civilian non-institutionalized population about the health and other characteristics of each member of the household. The interviewed sample for the 1992 NHIS consisted of 49,401 households containing 128,412 persons. Using census data and the interview results, NCHS staff estimate disease rates and impact for the U.S. population. A question was added to the 1992 core questionnaire that enabled identification of out-of-school youth (aged 12–21 years) by inquiring whether they were either now going or on vacation from school.

Infectious disease experts and officials report the number of infectious disease cases in many ways, offering insight into various aspects of a reported illness or cluster of illnesses. NHIS distinguishes between acute and chronic conditions, where acute conditions are defined as "a type of illness that ordinarily lasts less than 3 months"; chronic conditions last longer than 3 months. The survey only considers those illnesses that caused a person to curtail activities for at least a half a day or where a physician was contacted.

Incidence and Severity

Schools probably pose a greater risk to children than out-of-school environments for deaths from infectious diseases. There is no certainty that this is true because a school's contribution to disease is rarely determined. But school environments are probably incubators for fatal infections that can be spread through casual contact in classrooms. According to the vital statistics on the leading causes of death in 1992 (234), about 190 school-aged children died from pneumonia and influenza, two respiratory infections that can be spread via casual contact in classrooms. In the same year, 150 school-aged children died from infection with human immunodeficiency virus (HIV), virus that causes AIDS. HIV is spread through the exchange of bodily fluids (blood or semen) during sexual activity or intravenous drug use, or from contaminated blood transfusions, or *in utero* from the mother. Currently, there is insufficient information to evaluate the importance of school contacts in the transmission of HIV.

The NHIS data of the incidence and severity of infectious disease in school-aged children are shown in table 4-13. The table shows acute conditions in 1992 for children 5–17 years old, but does not represent all of their specific diseases. This population experienced about 82.3 million incidents of the acute conditions listed in the table, which are infective and parasitic diseases, such as common childhood diseases (e.g., measles), respiratory conditions such as influenza, and acute ear infections. This represents 73 percent of all acute conditions (about 112.3 million) reported in the NHIS survey (14), which also includes injuries and digestive system conditions. These infectious diseases were responsible for about 80 percent of the lost school days

The results of the NHIS can give an indication of the health impact of a particular condition. Respiratory diseases account for the greatest number of acute conditions, with influenza the most prevalent cause; accordingly, more school days are lost from respiratory conditions, and influenza is responsible for most of those. An analysis of the most school days lost per condition shows that "common childhood diseases" force a student to miss more school days for each case; pneumonia was the only other condition with a substantially greater loss of school days per condition than the others in the survey.

Several limitations exist with the NHIS data. The NHIS sample uses proxy interviews for all persons under the age 17. Because adults interviewed may be unaware of, or reluctant to report, certain health problems or use of health services by children, this information may not reflect the actual health status and utilization of services by youth in the household (229). The NHIS sample is too small to provide adequate measures of low prevalence conditions and suffers from having to rely on patient recall, which must also include the doctor's diagnosis. NCHS staff try to offset the effects of memory loss by requiring the patients to fill out the questionnaire once every two weeks (76).

Unlike the NHIS survey, which estimates disease incidence from a small sample population, national data on the reported occurrence of notifiable diseases are published routinely in the Morbidity and Mortality Weekly Report (MMWR) from the CDC. This publication contains summary tables of the official statistics for the occurrence of notifiable diseases for the U.S. in a calendar year and as such are the "authoritative and archival counts of cases" of notifiable disease (240). This information is collected and compiled from reports to the National Notifiable Diseases Surveillance System, which has morbidity information for 49 currently notifiable conditions, 42 reported weekly and seven annually.

OTA considers the reported cases in the U.S. for school-aged children, using the available three age groupings from 5–19 years old (see table 4-14). Gonorrhea was the most reported disease in this age group, with over 151,000 cases in 1992. This was about a fivefold greater

TABLE 4-13: Number of Acute Conditions and School-loss days in youths 5–17 years of age from the National Health Interview Survey, 1992

Type of Acute Condition	Acute conditions: Number (in thousands)	Acute conditions: Rate (per 100 youths)	School-loss days: Number (in thousands)	School-loss days: Rate (per 100 youths)	School-loss days/ condition
All acute conditions	112,340	239.9	164,797	351.9	1.47
Infective and parasitic diseases	21,155	45.2	40,751	87.0	1.92
Common childhood diseases	2,399	5.1	12,225	26.1	5.12
Intestinal virus, unspecified	5,122	10.9	6,312	13.5	1.23
Viral infections, unspecified	5,826	12.4	7,910	16.9	1.36
Other	7,808	16.7	14,303	30.5	1.83
Respiratory conditions	55,783	119.1	85,509	182.6	1.53
Common cold	16,562	35.4	21,978	46.9	1.32
Other acute upper respiratory infections	8,303	17.7	13,321	28.4	1.60
Influenza	27,653	59.1	43,532	93.0	1.57
Acute bronchitis	1,922	4.1	3,517	7.5	1.83
Pneumonia	584	1.2	2,001	4.3	3.58
Other respiratory conditions	758	1.6	1,160	2.5	1.56
Acute ear infections	5,424	11.6	7,149	15.3	1.32

SOURCE: Benson, V. and Morono, M.A.. Current estimates from the National Interview Survey, National Center for Health Statistics, *Vital Health Stat*, 10 (189), 1994.

number of cases than the second most numerous category, chickenpox, with about 30,900 cases. Hepatitis A had about 7,600 cases, and two diseases arising from contaminated food and water are the next most numerous cases: salmonellosis with about 6,000 cases and shigellosis with 5,200. Finally, authorities reported about 4,100 cases of syphilis and 3,000 cases of aseptic meningitis.

TABLE 4-14: Infectious Diseases—Summary of Reported Cases by Age Group, United States, 1992

Disease	Total (all ages)	5–9	10–14	15–19	5–19
Gonorrhea[a]	502,458	0	9,887	141,660	151,547
Varicella (chickenpox)	158,364	25,040	4,508	1,304	30,852
Hepatitis A	23,112	3,400	2,393	1,772	7,565
Salmonellosis	40,912	2,633	1,599	1,711	5,943
Shigellosis	23,931	3,526	1,002	665	5,193
Syphilis, primary and secondary	34,102	0	236	3,828	4,064
Aseptic meningitis	12,223	1,290	915	761	2,966
Lyme disease	9,895	775	553	392	1,720
Hepatitis B	16,126	100	211	1,105	1,416
Mumps	2,572	572	442	394	1,408
Tuberculosis	26,673	388	245	587	1,220
Pertussis (whooping cough)	4,083	422	410	304	1,136
Measles (rubeola)	2,237	210	159	325	694
Meningococcal infections	2,134	156	121	232	509
Amebiasis	2,942	150	103	97	350
AIDS[b]	45,472	102	57	133	292
Encephalitis, primary infections	774	89	73	54	216
Malaria	1,087	55	44	92	191
Hepatitis, unspecified	884	60	46	55	161
Hepatitis, non-A, non-B[c]	6,010	22	31	107	160
Typhoid fever	414	40	42	39	121
Hæmophilus influenzae	1,412	60	27	29	116
Rocky Mountain spotted fever	502	57	35	22	114
Toxic-shock syndrome	244	4	12	49	65
Rheumatic fever acute	75	14	16	7	37
Tularemia	159	22	10	3	35

(continued)

TABLE 4-14: Infectious Diseases—Summary of Reported Cases by Age Group, United States, 1992 (Cont'd.)

Encephalitis, post-infections	129	18	11	5	34
Rubella (German measles)	160	9	12	8	29
Brucellosis	105	6	6	10	22
Legionellosis	1,339	1	4	11	16
Leptospirosis	54	4	6	2	12
Hansen's disease (leprosy)	172	2	1	5	8
Cholera	103	1	2	3	6
Psittacosis	92	1	0	5	6
Plague	13	2	1	3	6
Trichinosis	41	1	1	3	5
Tetanus	45	1	2	0	3
Murine typhus fever	28	2	0	1	3
Diphtheria	4	1	0	0	1
Botulism total	91	0	0	0	0
Poliomyelitis paralytic	4	0	0	0	0
Anthrax	1	0	0	0	0
Rabies human	1	0	0	0	0

[a] Age data are collected on aggregate forms different from those used for numbers of reported cases. Cases aged 0–9 years are not shown because some of these may not be due to sexual transmission; however, they are included in the totals.
[b] AIDS total updated through December 31, 1992.
[c] The number of reported cases on non-A, non-B hepatitis is misleading because in some states, reported cases included persons positive for antibody to hepatitis C virus (anti-HCV) identified in routine screening programs who did not have acute hepatitis.

SOURCES: U.S. Department of Health and Humans Services. *Summary of Notifiable Diseases, United States, 1992.* Public Health Service, Centers for Disease Control and Prevention. *Morbidity and Mortality Weekly Report* 1992; 41 (55):10.

Certain other caveats exist for the data in this summary (229,240). Some diseases, such as plague and rabies, that cause severe clinical illness and are associated with serious consequences, are probably reported accurately. However, diseases such as salmonellosis and mumps that are clinically mild and infrequently associated with serious consequences are less likely to be reported. Moreover, the data are collected on a "passive system" where the attending physician or hospital personnel reports to the local health authorities. Thus, most low-impact illnesses will be underreported. Since the purpose of reporting is to mobilize health authorities to prevent the spread of the disease, reporting is done in accordance with strict case definitions of disease so that public health resources are not used for diseases of low impact (13,16,17).

Specific Diseases

Of all infectious conditions that may occur in school children, what makes certain diseases especially important to consider? The answer to this question provides a further illustration of the range and importance of infections among children in-school and the many dimensions of their impact. Based on interviews with infectious disease experts, OTA considers the following disease categories as warranting more attention than others based on their implications for schoolchildren and public health.

1. **Diseases with high incidence:** Diseases such as respiratory viral infections, especially influenza, are noteworthy because they occur so commonly. Other diseases of high incidence in schools include common childhood diseases and conditions such as headlice, conjunctivitis, strep throat, otitis media (ear infection), and mononucleosis (76). These conditions inflict costs not only on the child in terms of lost school days but also indirect costs due to parents' lost time from work.
2. **Diseases of high severity:** Diseases such as pneumonia, AIDS, and meningococcal infections (meningitis and bloodstream infections) that are not common but have a high case fatality rate (CFR) in school-aged children are a significant public health problem. CFRs refer to the deaths attributable to a specific condition in relationship to the reported cases of the condition. Bacterial meningitis used to have a fatality rate of more than 50 percent, but improved treatment has reduced the rate to 10 percent.
3. **Diseases with a major impact on the public health systems:** Diseases that occur in outbreaks in schools may deplete public health resources in an affected community. Such impacts may include investigation and intervention in foodborne disease outbreaks or mass immunization campaigns for meningococcal disease clusters.
4. **Diseases that spread from school children to families and the community:** Schools may act as an "incubator" for certain diseases that then spread to families and the community. Influenza and group A streptococcal infections are rarely severe in children but may cause substantial morbidity and mortality in infected family members, especially the elderly.
5. **Diseases that are becoming increasingly common ("emerging infections"):** Many microbiological agents can adapt and even mutate in response to their environment. Often these adaptations can result in organisms that can proliferate where they could not before, or previously harmless organisms can become disease-producing agents (104). These changes can create new infectious diseases (HIV infection and group A streptococcal toxic-shock syndrome), new problems associated with well-recognized infections (drug resistance in bacteria and tuberculosis), and changes in the epidemiology of infectious disease (clusters of cases of rheumatic fever). Infectious disease in the school environment is an important focus for studying these emerging diseases because it provides an opportunity for surveillance, research, and the development of preventive interventions.
6. **Diseases that offer substantial opportunity for prevention in schools:** This category includes diseases such as meningococcal infections and influenza, for which effective vaccines already exist; respiratory syncytial virus and parainfluenza virus, for which new vaccines are being developed that may offer the opportunity for prevention; foodborne illness, where application of proper food handling practices can eliminate outbreaks; and diseases such as hepatitis B and HIV infection, where schools provide a focus for education on risk factors for illness and on prevention through behavior modification.

The above disease categories warrant more attention than others based on their implications for school children and public health. Based on those categories, we briefly describe the available information on illnesses of school-aged children from these specific diseases: meningococcal infections, viral respiratory infections, group A streptococcal infections, hepatitis B and HIV infections, and food poisoning.

Meningococcal Infections

Meningococcemia, a disease characterized by the presence of *N. meningitidis* in the bloodstream, is transmitted from person to person by respiratory droplet or secretion contact (110). The illness occurs sporadically and in clusters, which have been reported to CDC with increasing frequency over the past three years (201). Based on the 1992 data on reportable diseases (240), the CDC estimates that approximately one-third of the roughly 2,100 reported cases of meningococcal infection in the United States each year occurred in school-aged children (5 to 19 years), with schools as a likely source for disease transmission (201).

Although most cases of meningococcal infection occur sporadically, disease clusters have been reported with increasing frequency since 1991. Whereas 11 clusters were reported in the 10 years from 1981 to 1990, 17 were reported for the four years from 1991 to 1994 (201). Of these 28 clusters, 12 (43 percent) occurred in schools, ranging from elementary school to college. In at least one cluster, disease transmission between children was associated with riding on a school bus. In several school clusters, additional cases occurred in siblings of school children or in the surrounding community (51,87). Of 14 "community" outbreaks where there was no identified institutional focus, almost half of the cases occurred in school-aged children, compared with less than 20 percent for sporadic disease, which suggests the possibility of transmission in schools for most outbreak-associated infection. The increased occurrence of outbreaks in schools and communities raises concern that meningococcal infections are a problem whose magnitude will increase in coming years (201).

The importance of meningococcal infections in school children derives not from the number of cases that occur but from their severity. The case fatality rate, which is the percentage of the number of persons diagnosed as having a specified disease who die as a result of that illness, is about 10 percent (13). Feigin et al. (51) reported that one death occurred in the seven reported cases (5 students and 2 siblings), while Hudson et al. (87) reported that one death occurred in nine reported cases (two students, five siblings, and outside of school contacts).

Viral Respiratory Infections

Viral respiratory infections are among the most common clinical illnesses in children. About 70 percent of the acute illnesses reported in the NHIS in school-aged children were "respiratory infections" in 1992; of those, 94 percent were classified as being "common cold," "other acute upper respiratory infections," or "influenza" (14). Although the morbidity of upper respiratory infections (URIs) is generally not high, complications such as otitis media (ear infections), pneumonia, and invasive bacterial infections may be associated with substantial morbidity and, in rare cases, mortality (34,64). Although they are typically thought of as high-frequency, low-impact conditions, they may be associated with severe disease or complications, especially in older family members who become ill after exposure to an ill child. Viral agents also cause lower respiratory infections such as pneumonia, bronchiolitis, and croup (141).

Transmission of respiratory viral illness occurs from person to person via respiratory droplets. A wide range of pathogens are responsible for viral respiratory infections. Common pathogens include rhinoviruses, influenza and parainfluenza virus, respiratory syncytial virus (RSV), adenovirus, and enteroviruses. Transmission may occur through infected aerosol or direct contact. Because transmission is increased by close contact and because their antibody levels are lower, the spread of infection is greatest in younger children.

The NHIS estimated that respiratory conditions (including otitis media) account for 70 percent of all lost school days associated with acute illnesses in children between 5 and 17 years of age. This translates to more than 92 million school days lost each year. In addition to the suffering of ill children and the disruption of their education, costs associated with these illnesses include those of the medical care (with more than 40 percent of infections being medically attended) and the parents' time lost from work.

School children are responsible for bringing influenza and other viral respiratory illnesses home and disseminating it into the community

(26,57,135). The 1976 influenza outbreak in Houston illustrates this point (57). During the initial stage of the outbreak, more than 50 percent of disease occurred in school children, while in later stages the proportion of disease in adults and preschoolers increased. The rate of infection in families with children in school was twice that of families without school children.

Group A Streptococcal Infections

Group A streptococcal infections, particularly pharyngitis, cause substantial morbidity of elementary school children among whom disease rates are highest and transmission readily occurs. In addition to the magnitude of disease, severe complications from rheumatic fever and invasive infections among children or their contacts make control of group A streptococcal infections important (72).

Group A streptococcal infections are transmitted from person to person by respiratory droplet and direct contact. More than 10 million episodes of group A streptococcal pharyngitis occur in the United States each year. Of these, approximately 80 percent occur in children, with the highest incidence of infection in children during the first few years of school (201). Transmission occurs readily in crowded school settings, with carriage and disease rates of >20 percent being common in classrooms during the winter and spring. Classroom and schoolwide outbreaks of pharyngitis and scarlet fever are reported commonly, although there is no surveillance for outbreaks and, hence, no tabulated data .

Despite the high incidence of group A streptococcal pharyngitis among school-aged children, the incidence of invasive infections[26] is lowest in this age group. However, children are likely to have a major role in introducing group A streptococci into a family, with older individuals developing invasive disease. In a CDC study of 12 clusters involving one or more persons with invasive group A streptococcal infection, the researchers found eight clusters included persons less than 20 years old, and 11 of 16 family contacts with pharyngitis or asymptomatic carriage occurred in this age group (202).

Hepatitis B and HIV Infections

Hepatitis B and HIV infection differ from other important infectious diseases of school-aged children in that transmission does not usually occur in the school setting. However, school-based educational programs represent a critical strategy for modifying the high-risk behaviors that make adolescence and young adulthood times of high risk for the acquisition of severe to inevitably fatal infection.

Hepatitis B virus (HBV) infection is a significant cause of acute and chronic liver disease in the United States and one of the leading causes of death worldwide among adults (74). An estimated 200,000 to 300,000 new HBV cases occur in the United States each year, approximately 50 percent of infections are symptomatic, and more than 10,000 require hospitalization. Over 250 deaths from fulminant disease (occurring suddenly with great intensity) and liver failure, and 5,000 from cirrhosis and hepatocellular carcinoma associated with HBV infection, occur each year. Approximately 25,000 new cases of hepatitis B occur in adolescents each year (201). Of these, almost 2,000 become chronic infections, with subsequent risk of cirrhosis and hepatocellular carcinoma. In addition, many of the 245,000 cases that occur in adults are contracted in young adulthood as a consequence of high-risk behaviors that likely began in adolescence.

HIV infections and AIDS represent the most important new health problem of the 20th century (104). HIV infection results in impairment of the immune system, with severe deficiency in cell-mediated immunity and the occurrence of opportunistic infections and death. HIV infection is the sixth leading cause of death among youth 10–19 years of age. Data from HIV/AIDS surveillance and seroprevalence suggest that new infections are occurring predominantly among

[26] Invasive group A infections occur much less frequently but may have severe consequences. Toxic shock syndrome, for example, has a case fatality rate of 30 percent and is characterized by the rapid progression of shock and organ failure.

younger populations than the earlier phase of the epidemic. Because of the long incubation period between HIV infection and AIDS, many persons reported with AIDS who are in their 20s were most likely infected as adolescents. Back-calculation methods suggest that 25 percent of persons reported with AIDS through heterosexual contact were infected as adolescents.

Both HBV and HIV infections are transmitted by contact with blood or other secretions from an infected person. Risk associated with exposure through sharing needles or sexual intercourse has been difficult to quantify. The risk of transmission from cutaneous or mucous membrane exposure is much lower. However, the risk of transmission of HBV and HIV infections is extremely low in the school setting, particularly when proper precautions are taken in the context of potential exposure to blood. Nonetheless, the behaviors of adolescents and young adults are major risk factors in disease transmission, therefore school-based programs will be a critical facet of a multidisciplinary approach to prevent the spread of infection (41).

Food Poisoning

Inherent in school lunch programs is the potential risk of foodborne illness. At various stages of food preparation, handling, and distribution, pathological microbes can be introduced into the food. Without the proper precautions, such as adequate refrigeration or heating, children may suffer from food poisoning in school. This is even more of a problem since children are at an increased risk for severe illness than adults (223).

Foodborne illness can result from contamination with pathogenic bacteria. People infected with foodborne bacteria may develop severe diarrhea, nausea, vomiting, and abdominal cramps (88). An estimated 9 million people become sick with foodborne illnesses each year, and 9,000 die (136). OTA could not find a database on the number of foodborne illnesses from schoolchildren eating contaminated food. Nevertheless, health officials have reported many outbreaks of food poisoning in the school-aged population. Some of the most common bacteria responsible for food poisoning are Salmonella and Shigella. In 1992, about 6,000 cases of salmonellosis and 5,200 cases of shigellosis occurred in 5- to 19-year-olds (240). Although these cases are to children of school age, they cannot be assumed to have occurred in school. These figures also do not include poisonings from other pathogenic bacteria such as *S. aureus* and *E. coli*. Moreover, many cases may be so mild as to warrant no report or were not recognized as food poisoning.

Few food poisoning outbreaks in schools have been reported in the academic literature. An outbreak of staphylococcal food poisoning occurred in 1990 in elementary schools in a Rhode Island community participating in a centralized school lunch program (179). The school lunch program included five schools, which sold 662 lunches. The bacteria were introduced into ham rolls that were inadequately handled by a food handler. The state Department of Health reported about 100 illnesses, all students. Another outbreak occurred at a Minnesota junior high school in 1988 (12). Among the 1562 students at the school, public health officials reported 32 cases of hemorrhagic colitis (inflammation of the colon resulting in bleeding) caused by *E. coli*-contaminated meat patties.

Infectious Disease Risks

Infectious diseases are among the best understood and documented causes of disease in school-aged children and a major source of morbidity and mortality. About three-quarters of all acute conditions reported in school-aged children were infectious diseases, which were also responsible for about 80 percent of the lost school days from all acute conditions. Two respiratory infections, pneumonia and influenza, that can be spread via casual contact in classrooms are among the leading causes of death for children under 15.

The transmission of disease through social interaction and the often crowded conditions at school suggest that schools are a primary incubator for the growth and spread of infec-

tious organisms. As such, schools probably pose a greater risk to children than out-of-school environments for deaths and illness from infectious diseases. There is no certainty that this is true because a school's contribution to disease is rarely determined; OTA could find little national data linking illness specifically to the school environment. Although case studies document the outbreaks of disease and disease clusters emanating from schools, more information is needed on the role of schools as a source for the spread of infectious and food borne disease.

CONCLUSIONS

OTA has identified the major hazards thought to pose a risk of illness to students in schools. Illnesses were limited to those resulting from exposures to environmental hazards and infectious organisms. Illnesses cause more lost school days than did injuries (even though injuries resulted in more fatalities than illnesses did): illness accounted for approximately 75 percent of the nearly 175 million school days lost from short-term conditions (both injuries and illness).

The diverse environmental agents examined in this report are grouped into four categories, as hazards related to school materials, indoor air, school location, and infectious diseases. Few data have been systematically collected on any of these hazards. OTA could not identify a functional national reporting system for environmental hazards in schools. **The absence of studies documenting in-school illnesses or exposure in school presents fundamental gaps in the data needed to assess risks nationwide.**

Relative to illness and exposure data, hazard identification data are more readily available. Both animal and human studies provide information about possible toxicity arising from exposure. Health consequences are well known from exposure to infectious organisms and to high levels of materials potentially present in schools: asbestos, lead, pesticides, and radon. What remains debatable, and probably will for a long time, are the levels necessary to increase a person's risk to a point at which interventions should be put in place. Moreover, each individual will vary in his or her response to the same concentration of agent.

Investigators have not sorted and often cannot sort out the effects of school and nonschool exposures. Exposure to an agent can come from the community or the school, or both. For many if not most environmental hazards, the total risk of adverse health effects reflects cumulative exposure to the culpable agent. Thus, students may be at risk for exposure to certain agents, but the relative contribution of school to the overall exposure is often difficult to discern. Clearly, schools can contribute to exposures to environmental hazards. While the school environment's contribution to overall risk can sometimes be calculated, it must be remembered that other environments—notably, the home—might expose children to these hazards as much or more.

Environmental hazards do not apparently account for more than 10 to 100 deaths per type of hazard annually. Deaths from cancer that might be related to in-school exposures to environmental hazards may not occur for many years after the exposure, and in-school exposure data, if they exist at all, are usually inadequate to estimate the risks for developing and dying from cancer. The concentrations of both radon and asbestos in the school environment are about the same as concentrations found in other buildings. OTA estimates that for a given school year, average in-school exposures to asbestos may result in two to 60 lung cancer deaths. OTA also estimates that average per year in-school exposures to radon may lead to about 60 lung cancer deaths above and beyond the lung cancer deaths associated with contributions from other sources of radon. There is considerable uncertainty associated with both these estimates, however, and the actual numbers of deaths associated with in-school exposures to asbestos or radon may be zero or many times higher. There is even more uncertainty associated with estimates of cancer deaths due to exposures to electromagnetic fields, because the biological effects of electromagnetic fields are not well understood and too few data exist on in-school exposures and their possible impact.

The spread of infectious diseases could occur either on or off school grounds and among school classmates, nonschool friends, or family. Schools probably pose a greater risk to children than out-of-school environments for deaths from infectious diseases. There is no certainty that this is true because a school's contribution to disease is rarely determined. But school environments are probably incubators for fatal infections that can be spread through casual contact in classrooms. Unlike injuries or illnesses from environmental hazards, certain infectious diseases must be reported, but records do not necessarily identify schools as the location of origin. OTA did not identify data specifying school etiologies; consequently, the data are reported for school-aged children.

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Using the Data 5

Chapters 3 and 4 of this report are compilations of information about health and safety risks in school. This chapter discusses how these data—along with other types of information—can help set priorities for risk reduction. In the end, surveys and studies of illness, injury, and death can provide only part of the picture. Decisionmakers are still faced with questions of which risks can be remediated and at what cost.

Moreover, even with good health and safety data (uncommon) and good information about the effectiveness and costs of risk reduction measures (even less common), the decision about which risks to focus on first would not be straightforward. These decisions go well beyond counts of illness and injury and costs of improvements, to difficult ethical, social, and emotional choices.

Inevitably, the course of deciding which risks matter the most leads to suggestions for the use of comparative risk assessment (CRA). Following a discussion of the different risk-related concerns, this chapter briefly explains CRA and the opportunities and problems it presents for making risk comparisons and deciding on priorities for risk reduction.

RISK DIMENSIONS

What is presently called "risk comparison" usually compares the number of injuries, illnesses, or deaths each risk may cause, without any other factor distinguishing them. Risk estimates alone do not necessarily relay the entire picture concerning the health effects involved, such as information on the nature of the death, illness, or injury, and the costs involved (13). The challenge for analysts is to present quite varied risks in rich, informative, and nonmanipulative ways. The starting point for broadening the scope consists of a fuller enumeration of the attributes or dimensions of risk.

It is natural for most people to order things by their size or severity, yet simple point estimates of risk often do not convey how risks, even of similar numbers of deaths, illnesses, or injuries, can differ. As an illustration of the importance of risk attributes beyond magnitude, consider the data presented in chapter 3 on deaths to students from school bus crashes and from in-school homicides. In both cases the severity is the same and the number of annual fatalities is roughly equivalent (40 to 50 cases in recent years). Nevertheless, there can be no doubt as to which cause of death is presently of greater public concern: school homicides. One indication of this public concern is the number of bills appearing before Congress on these issues. The 103d Congress introduced 61 bills dealing specifically with school violence and only two on school bus safety—of which one was a resolution for a "school bus safety week." Clearly, setting priorities involves more factors than just the number and severity of injury or illness.

This report discusses those risk attributes that can be considered in efforts to compare and rank diverse in-school risks, which inevitably involves value judgments as well as scientific estimates and measurements. It organizes the relevant risk attributes, or "dimensions," into three categories: magnitude of the risk; fear; and social contexts of the hazard (table 5-1).

The risk magnitude refers to the quantitative estimates of the likelihood of adverse health effects arising from the hazardous conditions. This category reflects the more conventional notions of the number of cases of injury and illness and their severity. There are several common measures for quantifying risk magnitude, some of which measure the individual probability of risk or the risk to the population. This report uses the number of incidents and incidence rates as measures of injury or illness in the school population and lost school days as a measure of severity. One measure of particular relevance in this report is in not treating all fatalities as equal; instead, the death of a child can be weighted more heavily than that of an adult, accounting for the additional years of life lost for the child.

Fear can be one of the most significant dimensions of risk, especially in schools, and one that varies widely across individuals and communities. Contributing to the fear of a hazard is the extent to which individuals can or cannot control the risk through personal action. Parents may fear their child's in-school exposure to asbestos or students carrying weapons because they cannot control these things, but they are probably less afraid of the exposures to infectious pathogens—even though bacteria and viruses are responsible for more lost school days—because they have more control from antibiotics, vaccines, and bedrest. The irreversibility

TABLE 5-1: The Dimensions of Risk

Category I: Magnitude

- Unweighted population-based measures of magnitude.
- Weighted population-based measures.
- Individual-risk measures that are independent of the number of persons at risk.
- Hybrid measures that incorporate characteristics of both population and individual-risk criteria.
- Measures that incorporate the concept of "background."

Category II: Fear

- Degree of fear.
- Degree of irreversibility.
- Degree of individual controllability.
- Degree of deferral to future generations.

Category III: Social Contexts of the Hazard

- Salience of blame.
- Degree of identifiability of those at risk.
- Benefits of the risky activity or exposure.
- Cost and feasibility of reducing risk.
- Risks of the intervention itself.

SOURCE: A. Finkel, "Comparing Risks Thoughtfully," unpublished contractor report prepared for the Office of Technology Assessment, U.S. Congress, Washington, DC, September 1994.

of an illness or injury also adds to the fear associated with a hazard; the more irreversible the effect, such as spinal cord injury or HIV infection, the greater the fear.

In contrast to magnitude, much of the social context of different risks cannot be readily quantified. Some risks are more worth taking—or bearing—than others. This difference is largely governed by the perceived benefits that accompany the risk. Football, for example, is among the most hazardous athletic activities—in terms of the number and severity of injuries—in which high school students participate; yet the perceived benefits of athletic accomplishment and social recognition encourage continued participation in it. The risk of a student dying in a car crash on the way to and from school may be high, but the risks are offset by the considerable time saved or the risks averted from having to walk home in the dark.

Analysts and decisionmakers must also consider impacts other than health, such as the disruption of the learning process that occurs from lost school days. One study found that absenteeism can present a social hazard, in terms of maladaptive behavior, difficulties in finding and maintaining employment, and welfare costs (20). Another intangible factor is the desire to focus attention on reducing risks where in so doing injustices can also be redressed and blame for the hazard can be affixed. Toxic releases from nearby hazardous waste sites or industry discharge generate more attention than comparable or even greater risks from radon because, in part, radon, unlike toxic releases, where a culpable polluter can usually be identified, is a natural gas and no one is responsible for its generation or its presence in indoor air.

The last category of risk attributes is an especially important consideration now confronting schools: the cost and feasibility of reducing risks. Small risks that are cheap and easy to eliminate may deserve priority attention, whereas even very large risks may not emerge as priorities from a thorough risk comparison—if reducing them would be technically infeasible or prohibitively expensive. Metal detectors, for instance, may provide added protection from firearms in schools, but they are expensive and school boards must decide if the risks at their schools justify the costs. Not only the cost, but the risk of the intervention itself, the dimension of "offsetting or substitution risks," arises whenever reducing one risk would create new risks in so doing. For example, closing the schools to remove asbestos exposes the children to risks of being out of school.

COMPARING RISKS

Risk comparisons are ubiquitous. Even though the most well-known types of comparisons involve environmental and human health risks, it is important to keep in mind that everyone has experience comparing many other risks as well. People may fear airplane travel and instead opt for travel by car—even though the risks of the latter are far greater. Some may fear bacterial contamination of fish and poultry or pesticides in their salads, yet are unconcerned about smoking cigarettes or drinking alcohol before driving.

To provide a context for the use of the data presented in this report, this section describes different types of comparative risk assessments, ways to conduct those assessments and, finally, factors to consider when setting priorities for risk reduction.

Types of Comparative Risk Assessments

Some analysts distinguish between two different types of comparisons that differ in motivation as well as methodology.[1] These comparisons can be called "small" and "large" CRA paradigms. "Small" CRA involves the quantitative side-by-side comparison of single risks. Ten or 15 years

[1] See A.M. Finkel and D. Golding (eds.), *Worst Things First? The Debate Over Risk-Based National Environmental Priorities* (Washington, DC: Resources for the Future/Johns Hopkins Press, 1994).

ago, the most well-known examples of "small" CRA were the juxtaposition of markedly dissimilar risks, often with one risk of the pair a voluntary risk and the other the result of an involuntary exposure. Such "hang-gliding is riskier than benzene comparisons" were performed and popularized for their supposed value in communication and public education (2). Some, however, viewed this type of analysis as manipulative and grounded in numerical sleight-of-hand rather than a neutral desire to inform and help put risks in perspective (3,14). In any case, the acknowledged intention of these efforts is to provide the perspective on a given risk with a comparison with others risks encountered in everyday life (see box 5-1).

Other types of "small" CRA are entering into current decisionmaking. The U.S. Environmental Protective Agency has recently begun to compare risks closely linked to intended regulatory actions; for example, the comparison of health risks of various automotive fuels and the ongoing assessment of the choice between cancer risks caused by the chlorination of drinking water and pathogenic risks due to the failure to disinfect.

"Large" CRA is a more recent phenomenon. It involves the comparison of categories of risks, and is increasingly being undertaken both for symbolic and practical purposes. The most prominent examples of "large" CRA have come from EPA's 1987 report "Unfinished Business" (18) and its 1990 study "Reducing Risks: Setting Priorities and Strategies for Environmental Protection" (19). Both reports explored whether setting agency priorities using, in part, a risk-based approach would save more lives and provide better protection without increasing the agency's total budget.

Many state and local governments are experimenting with CRA in ranking environmental problems by severity and comparing risk-reduction strategies. As discussed in box 5-1, at least

BOX 5-1: Comparing Risks in the States

At least 30 city, state, and tribal CRA projects are completed, under way, or in the planning stages. These efforts attempt to rank risks and priorities for environmental problems by incorporating qualitative information and value-laden judgments. Various experts in different environmental health fields provide their qualitative estimates of risk, but these estimates are broadened and enriched by public involvement. These studies are part of a nationwide effort by the U.S. EPA to help regulatory agencies in each state identify their most pressing environmental risks. The idea is to help cash-strapped states cope with growing federal environmental legislation and regulations by making it easier to compare the costs and benefits of proposed regulations to existing rules.

Comparative risk analysis deals with the full range of environmental problems and in large areas. It depends heavily on qualitative information and value-laden judgment in addition to the estimates of the magnitude of risk. Comparative risk analysis is a process that can be divided into two phases: risk analysis and risk management. In the analytic phase, participants try to understand how environmental problems affect the things they value, such as health or environmental quality. The first phase ends when participants rank the problems in order of their severity.

In the second phase, participants analyze and compare strategies for better addressing the problems they find are important. Most projects use an open process designed to bring the public into both the analytic design of the projects and the decisionmaking itself.

The ranking process is the key event in the first phase of a comparative risk project because it forces participants to make sense of all they have learned about the causes and consequences of pollution, the distribution of risk, and the quality of data and the uncertainties inherent in risk assessments. Although comparing dissimilar risks is not a technical or scientific process, the framework of comparative risk makes the process systematic, thoughtful, and illuminating.

SOURCES: Office of Technology Assessment, 1995, based on R. Stone, "California Report Sets Standard for Comparing Risks," *Science* 266:214, 1994, and R. Minard, "Comparative Risk Analysis," testimony presented at hearings before the Subcommittee on Technology, Environment, and Aviation. Committee on Public Works and Transportation, House of Representatives, U.S. Congress, Washington, DC, February 3, 1994.

30 city, state, and tribal CRA projects are completed, under way, or in the planning stages (11,16) (figure 5-1). These efforts attempt to rank risks and priorities for environmental problems by incorporating qualitative information and value-laden judgments. Various experts in different environmental health fields provide their qualitative estimates of risk, but these estimates are broadened and enriched by public involvement.

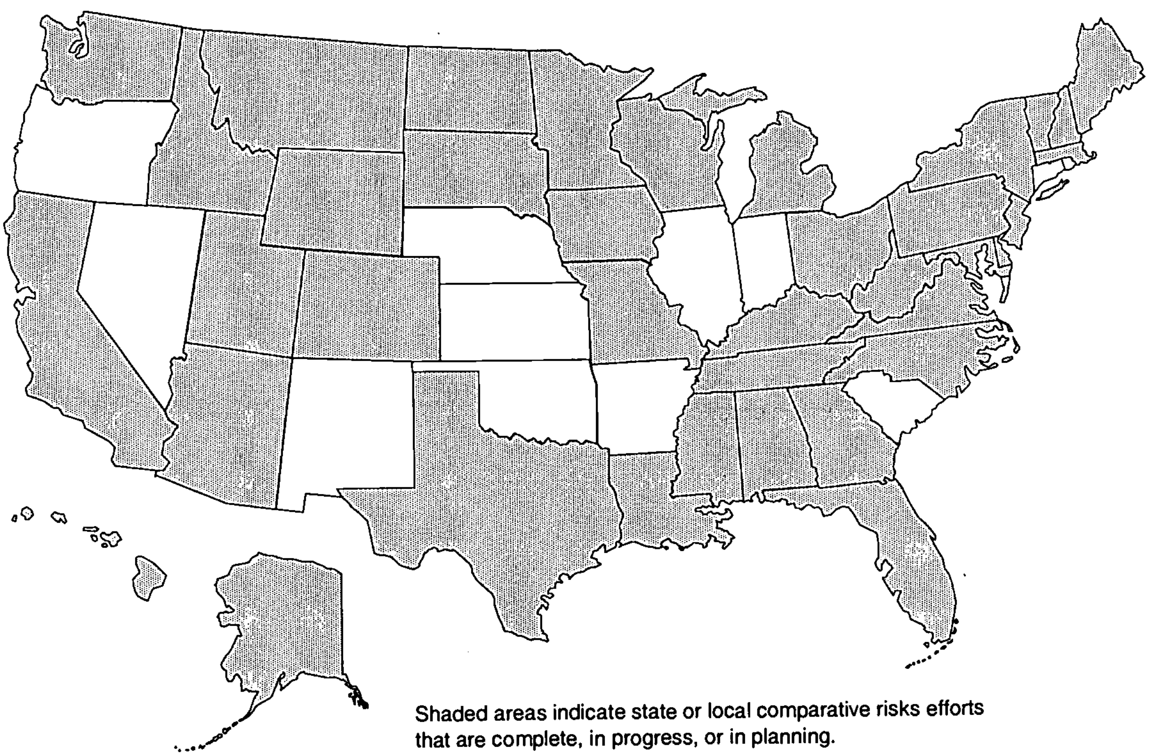
Conducting Risk Assessments

Whatever process society chooses for putting comparative risk assessment into practice, it ought to advance two distinct goals: provide a forum for identifying, and making judgments about, the "important" dimensions of the risks being compared, and provide a framework for asking, and moving towards consensus about, the real underlying question: "What should we do to make our schools safer, given that any intervention we undertake will use up resources from a finite supply?"

Much of the current discussion of the process for comparing risks revolves around the distinctions between the so-called "hard" version of risk-based priority setting and the "soft" version preferred by some other stakeholders (3,4). The design of the "hard" version—also referred to as "expert-judgment"—involves the use of a small group of experts to develop estimates of the magnitude of various risks, as well as a ranking of risk reduction opportunities. This strategy presumes that the experts can estimate the "actual risk" that will be different than the "perceived risk" of the lay public (15).

Some believe that the hard version can do more harm than good. Certainly, confining the ranking process to the experts, and further cir-

FIGURE 5-1: Comparative Risk in the States



Shaded areas indicate state or local comparative risks efforts that are complete, in progress, or in planning.

cumscribing it to deal only in the currency of "risk numbers," may not be productive in advancing social judgments on risks in schools, for two overriding reasons: 1) the conventional ranking tool—using risk estimates—is one-dimensional: many other dimensions may be of equal or greater importance than risk magnitude alone; and 2) even if magnitude is the most important dimension, exclusion from the process to determine the ranking will tend to cause resentment and mistrust among the affected citizens, in this case parents and their children (3,7).

The soft version has its problems too. In this paradigm, a representative group composed of citizens and experts would work together to generate a more impressionistic and less quantitative, magnitude-oriented ranking from a consensual weighting of the various dimensions that distinguish the risks under consideration. In this way the views and values held by those in the community can be incorporated into the risk-ranking activity. The obvious objection to the softening of CRA is that it allows people to make the subjective, soft dimensions, such as fear, as important—if not more so—than the quantitative information on risk estimates. From its critics' point of view, the soft version is just a polite way to describe the emotional, haphazard, inefficient way we currently set priorities. A perhaps less obvious but potentially more damaging criticism points out an irony—that while the soft version serves as a model alternative to the technocratic elitism of the hard approach, it may be no less vulnerable to being dominated by special interests (10).

For all the criticism, supporters of CRA argue that it is a logical extension of the less formal thought process individuals and governments already rely upon to help them make choices in all areas of human endeavor (3). Comparison and ranking inevitably involve value judgments as well as scientific measurements and estimates. One study suggests that qualitative characteristics of perceived risk are important to people in making decisions about new technologies (8). An open process, supporters claim, informs risk assessors about the values of those affected and the importance they place on these subjective risk attributes. Moreover, they claim that even if a CRA fails in establishing priorities, the effort would succeed in both educating and involving the public, engendering more public support for resulting decisions (17). As Fischoff states, "an objective determination of subjective values is needed to protect individuals from being exploited by society and society from being coerced by individuals" (6).

Lessons Learned

Regardless of the nature of the evaluative strategy, hard or soft, certain lessons can be learned from the limited attempts at CRA currently being conducted by local, state, and tribal governments. Few hard and fast conclusions can be drawn until more experience has been gained. Nevertheless, these CRA experiments reveal certain desirable features for CRAs.

The first lesson is to significantly involve the public. Public participation has proven an invaluable aspect of CRAs. By involving the public, a CRA can go beyond probability estimates of risk and incorporate ethical and political concerns, which are usually neglected in risk assessments (6,15). An open process informs risk assessors about the values and importance of subjective risk attributes, such as fear, to the community. Comparison and ranking inevitably involve incorporating these value judgments as well as scientific estimates and measurements.

The process also educates the public on the scientific and technical issues associated with risk assessment. The process should instruct everyone involved—parents, school boards, risk assessors, and others—about the nature of suspected risks. Risk comparisons can alienate people if the comparisons fail to inform them (5).

The next lesson is the need for a strong analysis of the available risk information and clear criteria for comparisons. The methods used by states and EPA (1,11) for risk analysis employ teams of experts to fashion a list of problems, sorted by types of risk—cancer, noncancer, ecological effects, etc. Using a variety of standards for comparison, the experts can first rank the problems within each type of risk and then relative to hazards of other types. The initial information that flows from these analysts to the public should be regarded as the first step. In addition to having a central role to play in evaluating the empirical and narrative information about the various dimensions of the risks being compared, the stakeholders may have much to contribute in structuring the criteria of analysis and supplementing the information itself. Having all participants agree to a common set of criteria and basing the analysis on those criteria make the results more understandable, as well as politically and socially acceptable.

The major obstacles to successful CRA projects come from the resource- and information-intensive nature of the process. Undertaking a CRA in a school district or state requires a large commitment from the school board, possibly the Mayor or Governor, and others involved in city—or statewide decisionmaking. Each project uses the expertise of researchers from a variety of public health fields, as well as substantial public involvement. The staff time and the financial backing necessary to see the project to completion may not be available in many cases. Not only are resources difficult to obtain, but as this report has shown, often inadequate data exist on which to make decisions with anything nearing useful certainty. Risk ranking requires considerable information on the nature of the risk and its potential impact on the community.

MANAGING RISKS

Setting priorities for risk reduction is more than simply ranking risks. As many observers have remarked, to set priorities means to guide where *resources* should flow (9). The biggest problems may bear no resemblance to the highest priorities for risk reduction. Large risks may have no socially, politically, technologically, or economically acceptable means of control or prevention, while small risks may be eliminated through actions that carry a small or even a negative economic price tag. Therefore, even if none of the social dimensions of risk are to be included in the analyst's attempt at risk comparison, decisionmakers and stakeholders need information on the feasibility and costs of *specific interventions* in order to judge where resources should go. These estimates may be as uncertain as the risk estimates and may add further complexity to the social process, but the alternative is either to rank the risks alone and have no guide for policy, or (perhaps worse) for decisionmakers to assume that the risk ranking equals the resource allocation.

Any commitment to a risk-control policy is likely to be supported by a web of beliefs about the magnitude of the risk and the effectiveness of the policy (5). Some of these beliefs will be accurate, and others erroneous. Still others will be half-truths, correct beliefs that ignore parts of the problem—such as the other uses for the resources being spent.

People may also be confused, caught up in the chaotic process by which risks are nominated for consideration. Alarming stories in the media may psychologically commit them to certain safety measures, such as installing school metal detectors or removing asbestos, and they may find it difficult to abandon these strategies. They may feel unbearable pressure to deal with minor risks that the media and others shove into the center of their field of vision.

Regardless of the sizes of the risks or the strength of public perception, limited resources constrain the possible alternatives for risk reduction. The purpose of comparing a wide range of risks in schools is to help allocate or reallocate resources among the many possible risk reduction options, including the option of no action on a certain perceived risk. The result of the process may be to reduce the controls on some risk-producing activities and channel resources elsewhere, into other risk-reducing activities or even activities unrelated to risk reduction.

Some observers criticize these "zero-sum" choices, where governments and school boards declare they can address only one risk or another (12). In fact, parents will likely view funds spent on school safety as nonnegotiable, and they may discount claims of fungibility: they will rarely accept a trade of more books for less safety. The public may accept funds being spent more efficiently, but not at a cost of visibly greater risks to students.

To such a combustible and emotional debate, the need for objective analyses, understandable information, and direct communication becomes increasingly clear. This report, then, consists of a first step in this process.

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