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ABSTRACT

This manual is intended to assist pesticide applicators in the area of aquatic pest control meet the requirements of the Michigan Department of Agriculture for certification. The Environmental Protection Agency (EPA) Aquatic Pest Control Guide served as a basis for this manual. The six sections presented describe: (1) Aquatic pest control; (2) Plant management; (3) Vertebrate management; (4) Invertebrate management; (5) Swimming pools; and (6) Environmental considerations and restrictions. A list of self-help questions and instructions for completing the questions are presented at the end of each section. At the end of this publication, units and conversion equivalents, formulas for herbicide application to channels, and formulas for herbicide application to ponds or lakes are presented. (HM)

Aquatic Pest Control

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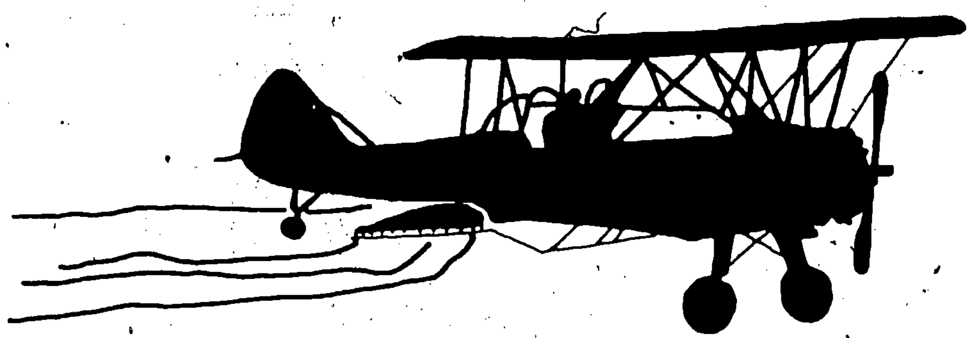

SAFE, EFFECTIVE USE OF PESTICIDES
A MANUAL FOR COMMERCIAL APPLICATORS

Extension Bulletin E-1032-5

AQUATIC PEST CONTROL

PREFACE

Federal regulations establish general and specific standards that you must meet before you can use or supervise the use of certain pesticides. This guide contains basic information to help you meet the specific standards for applicators who are engaged in aquatic pest control. While the majority of material in this guide pertains to vegetation management the guide also addresses aquatic insect and fungus control.

A list of self-help questions and instructions for completing the questions are at the end of each section. If you encounter difficulties in using the manual, please consult your county agricultural extension agent or representative of the Michigan Department of Agriculture for assistance.

Some suggestions on studying the manual are:

1. Find a place and time for study where you will not be disturbed.
2. Read the entire manual through once to understand the scope and form of presentation of the material.
3. Then study one section of the manual at a time. You may want to underline important points in the manual or take written notes as you study the section.
4. Answer, in writing, the self-help questions at the end of each section. Instructions on how to use the self-help questions in your study are included with the questions. These questions are intended to aid you in your study and to help you evaluate your knowledge of the subject. As such, they are an important part of your study.
5. Reread the entire manual once again when you have finished studying all of its nine sections. Review with care any sections that you feel you do not fully understand.

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AQUATIC PEST CONTROL

INTRODUCTION

The kinds and numbers of living organisms that dwell in and around an aquatic environment are determined by a wide variety of factors that can be divided into four major groups:

1. Climatic factors including light, temperature, wind and precipitation.
2. Structural factors, including shape of the body of water, its depth, the shoreline, configuration, the slopes of the bottom, the shape of the drainage basin and the surface area.
3. Soil factors, including the types of soils that make up the bottom and the shoreline of the body of water and the nutrients that are dissolved in the body of water.
4. The living organisms themselves, the plants and animals and the roles that they play, including producers (plants), consumers (animals), decomposers (bacteria).

Ultimately it is these factors and interrelationships of these factors that determine what kinds of living organisms and how many of them live in an aquatic environment.

When human beings attempt to make use of an aquatic environment, the living organisms present may be beneficial to that use or they may interfere with that use, or in many cases they may do both, especially when many uses are made of a single aquatic environment. When such a living organism interferes with a use, fortunately, aquatic environments that are ideally suited for a given use are often subject to misuse or overuse, and living organisms that heretofore had been beneficial to that use become over-abundant, and thus become a pest, or new types of organisms develop or are introduced, replacing the beneficial organisms and through over-abundance become a pest.

In these situations, control of such pests becomes extremely difficult because the only real solution, especially in the long run, is to correct the misuse or overuse that created the conditions suitable to the growth of these pests. It is important that a pest control operator be acutely aware of these interrelationships and fully realize that no organism is a pest until it interferes with human objectives. Then and only then is it a pest. For example, two common forms of aquatic plants in Michigan, naid and sago, are often considered to be aquatic weeds. These aquatic plants are not aquatic weeds, and are extremely beneficial, if the objective is to use the pond to favor waterfowl. Emergent aquatic vegetation, such as cattails and arrowhead, are not aquatic weeds if the objective is to provide spawning grounds for fish such as northern pike.

The understanding of relationships such as these is extremely important in order to avoid destroying something that is an important part of the ecosystem. Another example is the American lotus, a flowering emergent, which has an attractive blossom and a fruiting body often used in dry arrangements. It is also rare and considered endangered. If made aware of these facts, a pond owner may suddenly regard a weed as an attractive and unique ornamental to be preserved.

Such understanding is extremely valuable if the proper solutions are to be found. For example, in Michigan it is a common practice to construct septic fields between homes and lakes. This procedure often results in the pond or lake receiving nutrient-rich discharge from the septic field. When this occurs, some of the aquatic plants present will greatly multiply to take advantage of this enriched situation. In such a situation, the resultant aquatic vegetation is just a symptom of the problem; the problem is one of nutrient enrichment due to misuse. This control aimed at destroying the plant without correcting the situation which promotes their growth is prohibitively expensive and most often futile. Such symptomatic relief is usually temporary, or in many cases, the destruction of one form of aquatic vegetation will simply result in its replacement by another form. If light and nutrients are available, some plants will come forth to use them, unless the water is utterly poisonous, as in a chlorinated swimming pool.

Any pest control operator who ignores such concepts may misrepresent the service he is attempting to perform. Therefore, the effective control of aquatic pests requires the understanding of what constitutes a pest, why it exists, and how to select and apply the best combination of all appropriate control methods, including environmental, biological, mechanical and chemical. The information in this manual applies to the control of aquatic pests in:

- recreational waters used for fishing, boating and aquatic sports,
- agricultural reservoirs and water distribution channels used for stock watering, irrigation, and drainage,
- ornamental ponds
- coastal bays, estuaries, and channels, and
- drinking water reservoirs

AQUATIC VEGETATION

When aquatic vegetation becomes a pest, it is thus considered a weed. The first step towards prevention or control of these aquatic weeds is to identify them correctly. Most aquatic control methods are aimed at specific plants or groups of plants with similar growth habits. Aquatic plants can be grouped as follows:

- Emergent aquatic plants - plants that grow standing out of the water, or in water-saturated soils. Examples are cattails, bulrushes, and arrowheads.
- Submergent aquatic plants - plants that grow under the water surface. Examples are pondweeds, naiads, coontails and watermilfoils.
- Floating aquatic plants - plants that float on the water surface. Examples are duckweeds and waterlilies.
- Algae - plants without true stems, leaves, or vascular systems. Examples are waternet, pithophora and chara.

The following figures are intended as an introductory guide to the identification of aquatic plants and were taken from larger comprehensive works of Fasset, 1967 and Correll and Correll, 1972. Acknowledgement is hereby given to these sources. The detailed identification of aquatic plants is a highly technical task which requires the accumulation of a good library, a reference plant collection and years of experience. Those seriously interested in attaining a high degree of competence are referred to the selected references in Appendix 1 for additional and more detailed description of aquatic plants.

SELF-HELP QUESTIONS ON AQUATIC VEGETATION

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What is the first step toward prevention or control of aquatic weeds?

2. List briefly and explain the four groups of aquatic plants.

PLANT MANAGEMENT

Every aquatic plant management program should have two phases: a long-term phase and a short-term phase.

Long-term phase: Although commercial pest control applicators will rarely be involved in the application of long-term control methods, it is vital that they understand the importance and the role that they play in aquatic plant management so that they can better represent their services and integrate them into a total control program. Basically, long-term control is the control of nutrient input into the aquatic environment. Examples of sources of nutrient enrichment are domestic and industrial waste water, agricultural runoff, urban storm water runoff, septic tank discharges, lakeshore lawn runoff, soil erosion and sediment recycling. Thus, in the long run, aquatic plants must ultimately be controlled by proper land use, wise consumer use of commercial products, treatment of inflowing waters high in nutrients, diversions of water high in nutrients and municipal and industrial waste water treatment. For more detailed treatment of this subject, readers are referred to the Michigan Department of Natural Resources publication on Aquatic Plant Management.

Short-Term Phase: Short-term control methods include environmental, mechanical and chemical techniques.

Environmental Techniques

- Pond and ditch design and construction: Proper design and construction of ponds is an important factor in preventing aquatic plant problems. Shallow water at the margins of ponds provides an ideal habitat for emergent aquatic plants such as cattail. Submergent aquatic plants can easily become established there and then spread into deeper water. Banks should be sloped steeply so that there is very little water less than 2 or 3 feet deep.

  Proper design and construction of ditches and channels makes plant control easier in the future. If the banks are leveled and smoothed, hard-to-reach places will be eliminated. Lining canals with plastic will help in alleviating aquatic plant problems.

- Draw down, draining and drying: Some ponds, lakes, canals and ditches may be drained so aquatic plants will dry. The water levels in some large lakes and reservoirs may be lowered enough to expose plants in shallow areas. Drying periods of several months may be needed to control plants in some ponds and lakes. In canals, it may not be practical to interrupt water flow for longer than 3 or 4 days. The season of year and species of plant present may determine whether this method will be useful in a particular situation. Be sure to consider the resident fish species and their normal spawning times.

- Dredging: Dredging makes conditions less favorable for aquatic vegetation if the lake bottom is dredged to a depth below the depth of light penetration. Dredging may cause a temporary increase of silt suspended in the water, which though quite apparent, causes little harm. The availability of land to dispose of the dredged sludges can be a major problem. Although dredging is expensive, the effects may produce longer lasting benefits.

- Dilution or displacement: Dilution of low quality water with water of higher quality may lessen aquatic plant problems. However, a supply of higher quality replacement water must be available as well as an acceptable means of disposing of the lower quality of water. Further, this procedure may simply displace the problem downstream.

- Artificial aeration: Artificial aeration is the introduction of air into deeper water of the lake for the purpose of increasing the amount of oxygen in the water to promote the decomposition of organic sediments. Keeping oxygen in the bottom waters will reduce the release of nutrients from the sediments, and as long as nutrients remain chemically bound in the sediments in the deeper parts of the aquatic environment, they are less available for aquatic plant growth. Some disadvantages are that aeration may be detrimental to cold water fish by mixing warm surface water with lower water, and may increase the amount of sediment in the water. Artificial aeration, if applied at the wrong time or in the wrong situation, may kill fish and increase plant problems.

- Covering of bottom sediments: The use of sheeting materials such as black plastic and/or particulate matter such as sand or clay to cover the bottom sediments can perform several functions in controlling aquatic plants. It prevents exchange of nutrients from the sediments to the water and it retards the growth of rooted aquatic plants. Although bottom dwelling animals are usually eliminated by this method, the small scale of such applications has little effect in a lake ecosystem. Gas produced in covered sediments may rupture the bottom seal, causing it to float to the surface, if the seal is not adequately perforated to alleviate this buildup.

Biological Techniques

Biological control is presently the least developed and utilized of all aquatic plant management techniques. This method involves the introduction of an organism that competes with, preys upon, inhibits the growth of, causes disease in or parasitizes an existing plant. Limited success has been achieved in the tropics with the manatee, certain insects and fish. However, control in northern climates has not been demonstrated, or else the organisms have the potential to become pests themselves. For example, waterfowl, such as geese or swans, may consume rooted plants, but may also cause other problems such as swimmers itch, increased bacterial contamination of the pond, increased nutrient cycling, and consumption and defilement of lawns.

Mechanical Techniques

It may be necessary to use mechanical methods to control submersed plants. Sources of water for drinking, for livestock, and for fish ponds often cannot be treated with chemicals.

- Chaining may be practical in some instances, particularly in canals.
- Drag lines are useful for cleaning canals and margins of lakes and ponds.

- Cutters are used in both canals and lakes for cutting plants.

Some mowers simply cut the plants loose beneath the water surface. Others (aquatic plant harvesters) collect the plants for removal from the water. Disposal of harvested plants may be a problem but local landowners will usually pick up all the material because it makes excellent compost and mulch. Most methods of mechanical control fragment the plants. This may actually aid in the spread of most species of plants, since they may reproduce from the pieces. Mechanical control can be comparable in time and cost to the control of the same plant with chemical. Mechanical control can be restricted to a specified area, and if done at the proper interval, can give more long-lasting control than chemicals.

One form of mechanical control often overlooked is manual cutting and cleaning. For a small beach area or an area immediately around the boating and swimming dock, frequent manual raking or cutting of rooted plants will lead to their destruction because the plants will not be able to produce sufficient food to maintain their root systems. Like weeding a garden, it is advantageous to attack the plants during the early stages of development.

Chemical Techniques

Chemical control has, for many years, been the primary means of temporarily controlling aquatic plants. There are a number of chemicals available which offer varying degrees of action time, persistence, cost, selectivity and safety to humans, other mammals and aquatic animal life.

The best time to apply chemicals is during a calm sunny day after water temperatures have reached 50°F., or when plants first show signs of growth. For lakes where a large segment of the surface area is involved in the treatment the lake should be treated in sections over several days to avoid oxygen loss and consequently the loss of aquatic animal life as the plants decompose. Report immediately any environmental damage or death of large numbers of nontarget aquatic animals (fish, frogs, crayfish, etc.) to the Bureau of Water Management, Inland Lake Management Unit, Steven T. Mason Building, Lansing, MI 48926.

It is important that chemicals be used with extreme care. Those chemicals that are highly toxic to man require special handling such as protective clothing for application and posting of treated water so that innocent swimmers or fishermen are not exposed to potentially harmful chemicals. Before applying any chemical, always read the product label completely and follow all instructions. Take special note of all warnings on the label to avoid any personal injury, and dispose of all empty chemical containers.

A list of commercial applicators licensed by the Michigan Department of Agriculture to apply chemicals and other pesticides to the aquatic environment is available from the Department of Natural Resources, Inland Lake Management Unit. Additionally, the Inland Lake Management Unit is available to answer questions which may arise concerning chemical control of aquatic plants or other aspects of inland lake management.

When chemicals are part of an aquatic plant management program, special care must be taken to protect both the environment and individuals involved, since herbicides are potentially dangerous to both. To promote the proper use of pesticides, State statutes (Act No. 245 of the Public Acts of 1929, Act No. 58 of the Public Acts of 1959 and Act No. 41 of the Public Acts of 1955) have granted regulating authority over the application of these compounds to the Department of Natural Resources. Therefore, a permit is required from the Department of Natural Resources prior to any chemical treatment of waters within the public trust or private waters which discharge to waters within the public trust. Application forms for a permit may be obtained from the Department of Natural Resources Inland Lakes Management Unit, Steven T. Mason Building, Lansing, MI 48926.

It is important to point out that the use of chemicals to control aquatic plants has many drawbacks, a few of which should be mentioned. Most chemicals are nonspecific. In other words, even those aquatic plants which are desirable may be killed along with the undesirable plants. It is also difficult to control the drift of herbicides, consequently plants may be killed over a much wider area than intended. If too great a mass of vegetation is killed at one time, the decomposing plants may deplete the organisms in the water, resulting in a fish kill. Additionally, chemicals give very temporary control. For continual control treatments will have to be repeated for as many years as control is desired. In lakes where chemicals are used repeatedly on a large scale, dramatic shifts in plant populations can occur which may seriously alter the lake's ecology. To help prevent such alterations to lake ecology the Department of Natural Resources will not issue a permit in instances where treatment of more than one-half of the rooted aquatic vegetation is indicated.

Chemicals used in aquatic weed control can be grouped into three categories: herbicides, nutrient inactivators and shaders.

Herbicides: Herbicides are chemicals which poison plants; they are toxicants. Herbidides used primarily for control of algae are called algicides, even though they may also kill other aquatic plants.

Nutrient Inactivators: These are chemicals which, when applied to an aquatic environment, bind with or otherwise immobilize the nutrients necessary for plant growth. Once immobilized the nutrients settle to the lake bottom. Chemical substances used to immobilize and settle out nutrients usually contain a metal such as iron, aluminum or calcium. The settling process may also reduce suspended solids and decrease turbidity and color. In addition, when applied in sufficient quantity, these products may also serve as a nutrient barrier at the sediment water interface.

Shading Chemicals: These are inert chemicals which reduce light penetration in the water for prolonged periods. By reducing light, the chemical prevents plants from conducting photosynthesis and producing food, and thus limits their growth.

Control with Pesticides

Aquatic herbicides are available in several formulations.

Sprayable Formulations: Most herbicides are formulated to be mixed with a water carrier and sprayed. Some perform best as aquatic herbicides when applied into static or flowing water so that they disperse evenly and contact underwater surfaces of plants. Kinds available are:

- water-soluble powders or crystals that form true solutions in water,
- wettable powders that can be suspended in water and applied,
- water-soluble liquid concentrates that form true solutions in water,
- emulsifiable liquid concentrates that form ordinary "oil-in-water" emulsions in water, and
- special liquid concentrates that form "water-in-oil" emulsions (called

invert emulsions) when mixed with water and oil in the spray tank or when applied through special mixing nozzles.

Granular Formulations: Many aquatic herbicides are used as dry granules of various sizes. Kinds available are:

- granulated pure chemicals, such as crystalline copper sulfate,
- granules or larger-size pellets of clay and other materials impregnated with active ingredient, and
- slow-release granules or pellets designed to release the active ingredient in small amounts over an extended period of time in the water.

Application Techniques

Four zones of a body of water may be treated:

- the water surface,
- the water volume,
- the bottom 1- to 3-foot layer of water, or
- the bottom soil surface.

Surface Treatment: In areas of a lake where limited circulation exists (bay or channels) and/or plant infestations are particularly dense, only 1/4 to 1/3 of the treatment area should be treated at a time with approximately a three week interval between treatments. In this way the fish community is protected from oxygen depletion by plant decomposition. Surface treatments are employed where the product label designates dosage according to surface area such as lbs/acre or gals/acre. Surface acreage of a rectangular body of water equals length in feet times width in feet divided by 43,560.

Volume Treatment: As with surface treatments it may be necessary to treat particularly dense plant growths or isolated areas of a lake in segments to prevent oxygen depletion and resultant fish mortalities. Volume treatments are employed where the product label designates dosage according to volume such as lbs/acre-foot or gals/acre-foot. Free floating algae is one plant form controlled through volume treatment.

The concentration of chemical needed to kill aquatic plants is often very small and is stated in parts per million (ppm).

If the toxicity level of a certain chemical for a particular aquatic plant is 2 ppm of active ingredient, for example, the chemical should be applied at a ratio of 2 pounds of active ingredient to 1 million pounds of water in the area to be treated.

First, calculate the acre feet of the body of water to be treated. Multiply surface acres by the average depth in feet. An acre-foot of water weighs 2.7 million pounds. If one dissolves 2.7 pounds of any material in 1 acre-foot of water, there will be a concentration of 1 ppm by weight (ppmw). Use the following formula to determine the material needed to obtain a desired ppm concentration:

2.7 x ppm wanted x acre-feet = lbs required

Assume one wants to treat a pond containing 10 acre-feet. The concentration of active ingredient required is 0.5 ppm. Using the formula:

2.7 x 0.5 x 10 = 13.5 lbs of active ingredient

Bottom Layer Treatment: Treating the deepest 1 to 3 feet of water is especially useful in lakes where treatment of the entire volume of water is desirable. Such treatments are generally made by attaching several flexible hoses at 3- to 5-foot intervals on a rigid boom. Each hose is usually equipped with some type of nozzle at the end. They may be weighted to reach the depth desired. The length of hose and speed of the boat carrying the application equipment also affect the depth of application. Successful bottom treatments apply the herbicide as a "blanket" in the lower 1 to 3 feet of water.

Bottom Soil Treatment: Herbicide applications may be made to the bottom soil of a drained pond, lake or channel. Bottom soils may also be treated by applying granular formulations to the water that are designed to settled into the bottom soil.

Plant Control in Static Water

Static water is water in ponds, lakes or reservoirs that has little or no inflow and outflow. Even totally enclosed bodies of water often have appreciable water movement because of wind and other factors. Plants commonly grow in static water up to 12 feet deep. In very clear water, however, plants sometimes grow in water 20 feet or more in depth.

Floating and Emergent Plants

Sprayable formulations are almost always preferred for floating and emergent plants. These plants are killed by direct foliage applications of the spray mixture:

- by aircraft,
- with ground equipment, operated from the bank if the pond is small, or if plants occur only around the margins, or
- from a boat, using various types of booms or spray guns.

Submergent Plants and Algae

Herbicide formulations for control of submergent plants and algae in static water may be sprays or granules.

Sprayable Formulations: Herbicide sprays are most often applied as water surface treatments, particularly in shallow water. The herbicide is dispersed throughout the water by diffusion, thermal currents, and wave action. Sprayable herbicides can be applied under the surface by:

- injection through a hose pulled along behind a boat, or
- injection into the water by booms.

In all instances, control of the plants depends on good dispersion of the chemical in the water.

Sprayable herbicides sometimes are used for bottom soil treatments.

One of the best herbicide application strategies for static water is as follows:

1. Divide the lake or pond to be treated into segments of a size convenient to the situation and to the application equipment available. Mark these divisions with flags on shore and buoys in the water.

2. Survey each segment of the lake or pond, measuring length of shoreline, depth, surface area, or whatever is necessary to determine the amount of herbicide needed.

3. Calculate the amount of herbicide necessary to treat each segment.

4. Make the first application in the first segment along the shoreline, estimating the application rate as carefully as possible. The amount of material used in this first application run will enable you to more accurately estimate the rate of application necessary to apply all of the herbicide needed to properly treat the first segment.

5. Repeat the procedure described in number 4 above for each segment of lake or pond.

By using the above procedure, each segment of the lake will receive exactly the amount calculated as necessary, even if the amount applied on each application run is not exact.

Some sprayable herbicides may be applied from aircraft at low volumes of 5 to 10 gallons per acre, but drift is always a potential problem. The use of invert emulsions reduces the possibility of drift.

Both surface and injection treatments made by boat or ground equipment are more effective and are easier when larger volumes of liquid carrier are used. A handy sprayer for making applications by boat uses a special pumping system that draws water from the lake or pond as the boat moves along. Concentrated herbicide is metered into the pumped water to achieve the concentration required. This avoids both frequent interruptions to prepare spray solution and the need to carry water on board.

Granular Formulations: The main aquatic use of granular herbicides is for control of algae or submergent plants, although some are effective on certain emergent plants. Because granules sink to the soil surface, they perform about the same way as herbicides applied as bottom soil treatments. Application rates for granular herbicides may be based on:

- amount of herbicide per unit of surface area, or
- the concentration (ppm) that would be achieved if the same amount of herbicide were dissolved and totally dispersed in the water (total water volume treatment).

Granular herbicides perform best when distributed evenly over the water surface. They may be broadcast by hand or manual spreader over small areas. Special granule spreaders mounted on aircraft or boats are used for large-scale applications.

Advantages of granular herbicides are:

- treatment is usually confined to the bottom where the submergent plants are,
- they can be made to provide a long contact time with plants (slow-release granules),
- the herbicide concentration can be held to a low level, and
- they make it possible to use chemicals that in other formulations would be toxic to fish.

Plant Control in Large Impoundments

Herbicide applications that are successful in smaller bodies of water often perform poorly in large impoundments. These impoundments often have much water movement caused by thermal currents or the wind.

Plant control may sometimes be improved in these sites by:

- using the maximum recommended application rates,
- treating relatively large water areas at one time,
- applying herbicides only during periods of minimum wind,
- using bottom treatments in deep water,
- using granular formulations when possible, and
- selecting herbicides that are absorbed quickly by the weeds.

Plant Control in Flowing Water

Aquatic plants are difficult to control in flowing water since it is difficult to retain toxic levels of a herbicide long enough to achieve adequate control. Also the potential for contamination of downstream waters and the liability involved with such contamination place severe restrictions on herbicide use in flowing water. Additionally, since most herbicides registered for aquatic uses do not carry flowing water specifications in their labeling, such applications in many cases may constitute an illegal activity.

Plant Control in Limited-Flow Waterways

Flood drainage canals, sloughs and drains are good examples of limited-flow waterways. Plant control methods in these systems of little water movement are very similar to those used in static water. Consider the possible contamination of water used for other purposes when you plan the use of herbicides in limited-flow water. In some areas, drainage water may flow directly onto cropland or be used for irrigation, or it may enter a fishery or drinking water supply. In certain situations, flow may be stopped for the required interval before use. This procedure may also increase the effectiveness of treatment and reduce the amount of chemical required.

SELF-HELP QUESTIONS ON PLANT MANAGEMENT

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What is long-term control?

2. How should ponds and ditches be designed to prevent the growth of submergent aquatic weeds?

3. What factors must be considered before deciding to drain or dry out a particular body of water to control aquatic weeds?

4. Does a temporary increase of silt suspended in the water usually cause a significant amount of harm?

5. Can dilution of low quality water with water of higher quality simply displace the problem downstream?

6. What is artificial aeration?

7. List two results of covering the bottom sediments.

8. Is the introduction of an organism that competes with an existing plant an example of biological control?

9. List three mechanical techniques of aquatic weed control.

10. What is the best time to apply chemicals for aquatic weed control?

11. List the three categories of chemicals used in aquatic weed control.

12. List four types of sprayable pesticide formulations.

13. List three types of granular pesticide formulations.

14. Should the entire surface of a lake with limited circulation be treated at once?

15. How much active ingredient should be used to treat a lake containing 75 acre-feet with 20.5 ppm concentration of active ingredient?

16. Does the speed of the boat carrying bottom layer application equipment affect the depth of application?

17. Must herbicide applications for bottom soil treatment be made to drained bodies of water only?

18. What is static water?

19. What type of herbicide formulation is usually preferred for floating and emergent plants?

20. How are herbicides dispersed throughout the water?

21. List at least three advantages of granular herbicides.

22. List at least five ways to improve aquatic plant control in large impoundments.

23. Do most herbicides registered for aquatic uses carry flowing water specifications in their labeling?

24. List two advantages of stopping the flow of water in a limited-flow waterway for a certain interval before use.

VERTEBRATE MANAGEMENT

Fish

As with all organisms, fish may become pests when they:

- compete with more desirable fish for food, space and other necessities of life,
- prey or feed upon more desirable fish,
- are desirable for a given use but have become over-populated and stunted,
- affect man's interest or livelihood.

Control

The control of fish populations most often involves the removal of exotics, such as goldfish or lampreys, or of rough fish such as carp or suckers, or of less desirable fish, such as pike, for the benefit of desirable game fish. In many cases it is necessary to remove all fish because one or more species has become overabundant and stunted.

The control of pest fish varies with each situation and species. Some problems are not serious enough to justify any action. In other situations, control is necessary and can be justified on sound biological grounds.

Nonchemical control: includes temporary draining of small bodies of water or using physical methods such as traps, nets or screen barriers, or barrier dams.

Chemical control: requires the use of pesticides, or fish toxicants. The use of fish control chemicals is a highly specialized area of pest control. Few chemicals are registered for this purpose. Use special care when applying them. A permit is required from the Fisheries Division, Michigan DNR. The amount of fish toxicant required is determined in the same way as is the amount of herbicide needed (see section on herbicides). However, because fish are mobile and can avoid treatment if possible, application strategy is as important as rate of application and uniform treatment. It is important that all areas that potentially harbor fish be treated, especially shallow areas and under water sources. Treatment should be completed in as short a period as possible, preferably one day. Some wave action is desirable to disperse the chemical; otherwise running a motor boat may be necessary to mix the chemical thoroughly with the water. Since all pesticides are affected by water temperature, application time and rates must be adjusted according to water temperature.

MAMMALS

Rodents cause the most serious problems. They include:

- beaver,
- muskrats, and
- rats

Damage includes:

- burrowing, which structurally weakens earthen dikes, levees and dams; causes water losses or flooding; and increases erosion of banks;
- increasing suspended sediment in water;
- clogging culverts or water pipe intakes with vegetation cut during feeding or nest-building activities, resulting in flooding of crops, trees, roads, etc;
- blocking stream flow, resulting in flooding;
- consumption of desirable aquatic vegetation or girdling of woody vegetation.

Control

Depending on the pest causing the damage and the situation, the following control methods may be used:

Nonchemical control, including:

- modifying or controlling habitat, such as controlling plants to reduce
- installing dike protectors or barriers,
- trapping, or
- shooting.

Chemical control, including the use of:

- repellents,
- fumigants, and
- poison baits.

Application

When using poison baits, it is important to use a bait the animal will accept and to place it where the animal will accept it but where other animals are unlikely to find it. Poisoned diced carrots placed in muskrat burrows or in floating bait boxes are likely to kill only muskrats. An important point to remember is that where abundant habitat exists for a pest, lethal controls provide only temporary relief at best.

Often they are futile. For example, lethal techniques for muskrats in a pond adjacent to extensive marshland are not likely to prevent damage. Lethal techniques for muskrats in a pond isolated from additional muskrat habitat may be very effective. Shooting, trapping or poisoning of beaver and muskrats requires a permit from Law Enforcement Division, MDNR.

Other Vertebrates

Birds, reptiles and amphibians occasionally cause local problems. Chemicals are rarely used to control them directly. Birds are usually repelled with auditory repellents. Reptiles and amphibians are usually discouraged by destroying the habitat they require; turtles are commonly trapped. Insecticides may also be used on the insects present in the area, thus reducing the food supply that would attract reptiles and amphibians.

SELF-HELP QUESTIONS ON VERTEBRATE MANAGEMENT

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List four instances in which fish may be considered pests.

2. List at least four methods of nonchemical control of fish.

3. Is a permit required in order to apply fish control chemicals?

4. List four types of damage caused by mammals.

5. List at least three methods of nonchemical control of mammals.

6. List three common methods of chemical control of mammals.

7. Do lethal controls provide good control of pests in areas where abundant habitat exists for a pest?

8. Are chemicals usually used to control birds, reptiles and ampibians?

INVERTEBRATE MANAGEMENT

SWIMMERS' ITCH

Swimmers' itch is caused by tiny larvae, 1/32 of an inch long, called cercariae, which penetrate into the skin of a human. Cercariae are a free swimming intermediate stage in the life cycle of blood flukes. The adult blood flukes, called schistosomes, live as parasites in the tissues of certain mammals and birds, usually those associated with ponds, lakes, and streams. The cercariae of about twenty different kinds of schistosomes are known to penetrate the skin of man and produce a rash. Complete life histories are unknown for many of these pests. The typical cycle of the species which causes the majority of itch cases at Michigan swimming areas involves water birds and snails.

Life History

The adult fluke, a very small worm, lives as a parasite in the tissues of a suitable host, particularly certain waterfowl. Eggs from the parasite are passed into the water with droppings of the bird. A single, very tiny swimming form called a miracidium is produced from each egg that hatches. These miracidia swim and drift about in search of particular kinds of snails. If the miracidia cannot find a suitable species in a few hours, they will die. However, if they locate a suitable snail, they penetrate into the body through the soft parts. Inside the snail the miracidium undergoes changes which finally result in the production and release of many cercariae. This state of the parasite life cycle may be seen by placing an infected host snail in a small jar filled with water. After an interval of several hours cercariae shed by the snail will appear as small moving specks in the water. The cercariae swim freely and drift about, waiting for suitable final hosts, such as certain species of ducks, to come close enough for them to make contact. Few cercariae live much longer than 48 hours. On finding a proper host the cercariae penetrate through the skin, enter the blood stream and develop into adult blood flukes, thus completing the life cycle. On finding a human, the cercariae penetrate the skin and cause the irritation called swimmers itch. Since the human is the wrong host, the cercariae eventually die, but not before causing considerable discomfort.

With our present knowledge of the relationship between schistosome cercariae and snails it follows that eradication of snails would eliminate the swimmers' itch problem. However, obtaining a total snail kill in a large lake would be a practical impossibility with present control methods. In attempting such an eradication there would also be danger of seriously affecting the fish and fish-food populations. Thus a universally satisfactory molluscicide has not yet been identified, although research is being conducted towards this goal.

Application Methods and Equipment

Treatment methods are normally aimed at getting the chemicals down to the snails on the lake bottom. Best results are achieved by releasing the chemical, normally a heavy granule, under water just above the beach floor. This procedure is usually accomplished with motor-powered units designed to pump the chemical through flexible tubing which drags along the lake bottom as the treatment vessel moves through the infected area. If this type of distribution equipment is not available, fair results can be obtained by broadcasting the granules on the water surface and allowing them to sink to the lake bottom.

If application of the necessary chemicals is made at the proper rate, free-swimming fish should not be killed. They will move out of the area. However, since molluscicides currently used in swimmers' itch control are toxic to fish, treatment should not be made until pan fish and bass are off their spawning beds in shallow water, usually after the middle of June in lower Michigan. Bottom organisms such as leeches, aquatic worms, and insect larvae may also be killed. Some of these animals are used by fish as food but their loss is unimportant when the whole fishfood producing area of the lake is compared to the treated area. Ratio of untreated area to treated is normally at least 50:1 or 2.

The snails responsible for the swimmers' itch problem are the ones which need to be controlled. It is better to locate the infected snails before treatment than to chance missing the infected snail bed. A survey of snails for cercariae and a pretreatment beach inspection will usually solve this problem.

A large enough area must be treated. Aided by winds and wind-created currents, cercariae may stay together in sufficient numbers to create a swimming beach hazard quite a distance from the snail bed. Treatment of 1,000 feet of lake frontage is recommended as minimum. This usually entails securing the permission and cooperation of several landowners along the shore. Where infected snails are uniformly distributed, the area treated should extend from shore to the drop-off. Of course, local conditions will normally determine the actual area to be treated.

Treatment should not be attempted when the lake is rough. The chemical will be dispersed throughout the water by excessive wave action and will drift out of the treatment area rather than remaining on the bottom in the desired location. A little wave action is desirable to aid in distribution, but treatment on a windy day is a waste of time, money and effort.

Mark the area to be treated and divide it into small enough plots so that distribution can be even and at the proper rate. Wire-centered plastic clothes line with floats attached every 50 feet is very satisfactory as a marking and measuring device. It is usually best to commence treating next to and parallel with the shore and work towards deeper water.

Precautions

Swimming and the use of motor boats should not be allowed in the area of treatment for 24 hours following chemical application. While there is little danger to swimmers from the chemicals, safety dictates keeping out of the water for this period. This restriction also prevents the layer of chemicals from being disturbed. Agitation of the water would cause mixing with bottom materials. A subsequent loss of effect would result. There are also indications that dying snails release large numbers of cercariae.

MOSQUITOES

Mosquitoes are undoubtedly the most bothersome insect pests found in Michigan. Over 50 different species of mosquitoes are known to be present in Michigan, and individual feeding habits and seasonal abundance of these species assure the presence of mosquito problems throughout Michigan during nearly all of the months of spring, summer and fall.

Mosquito species vary greatly in flight range habits and capabilities, biting preferences, abundance, and type of habitat most suitable for their development. All species have four distinct stages in their life cycle and the immature stages of every species develop only in water. An adult female mosquito may lay up to several hundred eggs during her lifetime. The location selected for depositing these eggs varies with species. Those deposited directly on water surfaces usually hatch within a short period of time, but eggs deposited on damp or even dry soil, in depressions subject to periodic flooding, may survive for prolonged periods. The eggs of some species, including some of the most common mosquitoes in Michigan, can remain viable up to a year or more on moist or dry soil before they are flooded and hatch.

The larvae, often called wrigglers, emerge from the eggs and feed upon minute forms of animal and plant life and decaying organic matter in the water. When fully grown, they develop into pupae. The pupal stage of the mosquito, also called a tumbler, involves a transition from the aquatic form to the adult. When this transition is completed, the pupal skin splits along the upper surface, and the adult pulls itself up and out of the floating skin on which it rests until ready to fly. Development time from egg to adult varies with temperature, and may be as short as 7 to 10 days in midsummer.

Only the female mosquito sucks blood, using this nutrient for development of eggs. Feeding preferences of adult females and distances they may fly to obtain a blood meal are usually quite specific for a given species, but vary widely between species. Some species feed only on birds, some on wild game, and others on domestic animals and man. Certain species may fly many miles from their larval habitat while others rarely go beyond a half mile. A number of species found in Michigan are such fierce biters, and appear in such large numbers, that they make some areas nearly uninhabitable. They can even pose a threat to the existence of some wildlife during the warmer times of the year.

Mosquitoes create both direct and indirect human health hazards. Most obvious are loss of sleep due to night-biting mosquitoes, irritation from bites, and secondary infections from scratching bites. Reduced efficiency of workers is a less obvious, but important, consequence of large numbers of biting mosquitoes. At least four mosquito-transmitted diseases—dog heartworm and the California, St. Louis and Eastern equine encephalitis forms—occur in Michigan and adjacent states. These are normally animal diseases, but can be transmitted to humans. So mosquito control is a matter of both comfort and health protection.

Mosquito Control

Mosquito control operations may be directed against the larval or adult stage of the insect, or both. However, the most satisfactory and long lasting control of mosquitoes is accomplished by eliminating or modifying existing water accumulations so they are not suitable for mosquito larvae. These permanent control operations normally are beyond the capabilities and resources of individuals or commercial controllers and require governmental participation. Commercial pest control operators are most often involved in mosquito control in areas where no community control program has been established or where existing programs are inadequate.

Temporary Larval Control

Insecticides used to control mosquito larvae are called larvicides and the degree of control obtained with larvicide applications often depends upon the degree of water pollution and the type and amount of vegetation cover present. If cover is heavy or organic matter in the water excessive, it may be necessary to increase the concentration or volume of the insecticide used. Granular insecticide formulations may be required to treat water accumulations covered with dense shrubbery, grass or other types of emergent vegetation since liquid formulations are deposited on the surfaces of the plant cover and do not reach the larvae present in the water. Water in containers that cannot be drained or removed from the area should also be treated with larvicide. Frequency of larvicide application varies considerably with temperature and mosquito species, but must be often enough to prevent larvae from developing into adults. Applications each 10 to 14 days are normally adequate for Michigan summer conditions. All potential larval breeding sites within adult flight range of the controlled area must be treated if satisfactory control is to be achieved.

No larval control operations should be initiated until it has been determined that the water to be treated does contain mosquito larvae and pupae, and that they are species that actually bite humans.

Temporary Outdoor Adult Control

Insecticide mists or fogs are most commonly used to reduce adult mosquito populations to an acceptable level in outdoor areas. Both fogs and mists are applied as space treatments that depend primarily upon the wind for distribution. Neither mists nor fogs should be applied in winds of more than five miles per hour. Optimum windspeed is two to three m.p.h. in open areas and slightly higher in forested areas. For best results, air temperature near the ground must be cooler than at six feet or more above the ground. This condition, called a thermal inversion, assures that insecticide particles will stay close to the ground where most flying and resting mosquitoes occur. Thermal inversion occurs naturally from late evening until sunrise, so the most effective fogging and misting operations are conducted at night.

Fogs applied during the heat of the day nearly always rise rapidly, disperse in the air, and are totally ineffective in controlling mosquitoes. The effectiveness of mists is also greatly reduced when used during the day. Insecticide fogs have no lasting effect so they must be reapplied whenever the number of mosquitoes increases beyond the "level of acceptance." Mists may provide a slight residual action but their primary effectiveness results from direct contact with mosquitoes. Mists may be applied under a wider variety of atmospheric conditions than fogs, but have the disadvantage of poorer penetration of vegetation. When oil-base insecticide formulations are applied as mists, they may burn foliage or produce objectionable residues on laundry, automobile paint and windows unless care is exercised in the operation of the misting machine.

Persistent insecticides formerly available in Michigan (DDT and related chlorinated hydrocarbons) provided effective adult mosquito control when applied as a residual spray to vegetation in a belt at least 20 feet wide, surrounding the areas to be protected. However, insecticides now approved for use in Michigan usually will not persist long enough to provide satisfactory control when used in this way. When applied as residual sprays to protected areas on the outside of buildings, cabins, sheds and other locations not exposed to rain or dew, presently approved insecticides may be used to supplement other control methods. When applied only as residual sprays, these insecticides usually will not reduce the number of adult mosquitoes to an acceptable level.

Temporary Indoor Adult Control

Aerosol space sprays are recommended for immediate indoor control. This type of spray is usually more efficient if the treated area is kept closed for at least 15 minutes following treatment. Resin strips impregnated with insecticide may also help to control adult mosquitoes indoors, but are effective only if the space is enclosed and there is minimal air exchange. This type of control should not be used in food preparation and serving areas, nurseries or facilities in which infants, aged or ill people may be exposed to the vapors.

BLACKFLIES

Blackflies, sometimes called "buffalo gnats," are small black or gray flies with stout, humpback bodies, short, broad wings and short legs. They feed on the blood of wild or domestic animals, and birds. In some parts of Michigan, they are particularly vicious pests of humans. The blackfly season is longer than that of most other blood-sucking flies. The first adults appear late in April, reach their biggest numbers in May and June, but persist in diminishing numbers until late October.

In some areas of Michigan, blackflies become so numerous that it is nearly impossible to remain out of doors. Blood loss from their bites has resulted in death of both domestic and wild animals. If the blackfly is not seen while biting, its bite is readily recognized. There is no pain while the fly punctures the skin and feeds, but the site of the puncture is usually marked by a small trickle of blood which appears after the fly has finished feeding. Within an hour, the area around the bite swells and an intense itching begins that may last for several days. Some individuals become sensitized to blackfly bites and also suffer pain and severe swelling in the area of the bite. Occasionally, there are additional reactions or extreme swelling requiring hospitalization.

Unlike mosquitoes, blackflies bite only during the day. When feeding on animals, they crawl through the hair or feathers to the skin, or enter the ears and nostrils to bite. On man, they usually feed on exposed skin, but may crawl through openings in the clothing to bite covered parts of the body.

Blackflies lay their eggs in a variety of places, but all are either in running water or its immediate vicinity. One female may deposit as many as 500 eggs in her egg-laying period—usually in masses on stones, vegetation or other partly submerged objects—at, or near, water surfaces where they are immersed or continually wetted. Eggs hatch in 4 to 12 days and larvae attach themselves to stones or plants in the stream with a small suction disc and fine silken threads. The larva transforms to a pupa and is firmly attached within a silk pupal case spun by the larva just before pupation. Duration of the aquatic stages varies from two to three weeks to several months, depending upon species, temperature and other conditions.

Upon emerging from the pupal skin, the flies take flight immediately and may live from a few days to several weeks. While some species have only one generation each year, others have two or more. In general, southern Michigan species have multiple generations each year. Generations of the various species overlap so that all stages of blackflies may be present in a given area most of the summer. Some species overwinter as eggs and others as larvae. There is little precise information concerning the flight range of adults, but one prairie species in Canada has reportedly attacked livestock as far away as 100 miles from its source. The most common species in Michigan are not likely to fly this far, but still have relatively long flight ranges.

DDT provided the most effective blackfly larvae control ever formulated, but its use has been restricted in Michigan, and there is no alternate insecticide that produces the same effective larval control. Outdoor space sprays recommended for most adult mosquito control offer some local temporary relief from blackflies. Probably the most effective way to prevent blackfly bites is to apply insect repellent to exposed skin areas and keep clothing tightly fastened.

BITING MIDGES

This group of biting flies includes several types of very tiny insects known as "punkies," "sandflies" and "no-see'ums." Those that feed on humans bite mainly in the evening and very early morning. The burning and irritation they cause is far greater than would be expected from an insect of this small size.

Again, elimination of suitable breeding sites is the most effective method for control of these pests. Location of these areas, however, is an extremely long and tedious task, even for a trained expert. Biting midges usually develop in the bottom mud of ponds, marshes and swamps or other similar wet soils, rich in organic material. The minute size of the larvae makes it extremely difficult to locate their breeding sites. If breeding areas can be located, drainage, diking or deepening the margins of ponds and streams may provide effective control.

Due to the limited flight range of the adults, these flies can be easily controlled in localized areas with the same insecticide mists or fogs used for adult mosquito control. Biting midges are weak fliers and are greatly inhibited by even moderate to light winds. Keep grassed areas closely mowed, shrubbery and low vegetation away from human and animal habitations, and thin trees and shrubs to encourage stronger wind currents.

Biting midges are also attracted to lights. Their tiny size enables them to enter tents, cabins and cottages through average mesh screen. Indoors, an aerosol containing either pyrethrum (pyrethrins) or allethrin is effective. Fortunately, the weak flying ability of this group of insects restricts their nuisance to very limited and localized areas.

SELF-HELP QUESTIONS ON INVERTEBRATE MANAGEMENT

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. What causes swimmers' itch?

2. Are humans natural hosts of the organism causing swimmers' itch?

3. Why should chemical treatments for swimmers' itch not be attempted when the lake is rough?

4. How long after chemical application for swimmers' itch should swimmers and motor boats be excluded from the area?

5. Do all species of mosquitoes feed on humans?

6. What is the most satisfactory and long lasting control of mosquitoes?

7. Are mosquito larvacide applications 15 to 20 days apart normally adequate for Michigan summer conditions?

8. What are the optimum weather conditions for application of mists and fogs to control adult mosquitoes?

9. Under what conditions are resin strips impregnated with insecticide most effective for mosquito control?

10. Do blackflies feed in the early morning and late evening?

11. What is the most effective method for control of biting midges?

SWIMMING POOLS

THIS SECTION IS PROVIDED FOR THOSE PERSONS WHO APPLY "PESTICIDES" TO SWIMMING POOLS AS A BUSINESS. The purpose is to provide practical information considered to be important for the safe and effective use of pesticides in both private and public swimming pools.

Public swimming pools are regulated by the Michigan Department of Public Health under authority of Act No. 230, Public Acts of 1966. Persons who apply pesticides in public swimming pools should obtain a copy of Act No. 230 and become familiar with the rules and regulations promulgated thereunder.

Swimming Pool Disinfectants

Disinfectants are agents, either chemical or physical, which destroy or remove disease-causing microorganisms or "pathogens." Swimming pool water is disinfected to prevent the transmission of disease. Sterilization of the water—the destruction of all the microorganisms in it—is unnecessary because many of them are not harmful.

The ideal swimming pool water disinfectant is highly biocidal, quick acting, nontoxic to humans, homogeneous, readily soluble, simple to use and test, compatible with other chemicals used, stable and noncorrosive both in storage and in use, readily available, inexpensive, and not taste or odor producing. No disinfectant has all these characteristics. Few have most of them.

The search for the perfect disinfectant continues. Some products show promise, but others are inadequate and unacceptable. Before a new disinfectant is used, the health department should be contacted for confirmation that it is satisfactory and approved.

CHLORINE

Chlorine, in its various commercial forms, is the most widely used swimming pool disinfectant. It has proven effectiveness and is readily available, relatively inexpensive, and easy to store, apply, control and test. It is useful also as an algicide, as a floor and deck sanitizer, and to oxidize or "burn up" foreign matter in the pool water.

Chlorinated swimming pool water should have a free chlorine residual of at least 0.4 to 1.0 part per million and a pH preferably of 7.2 minimum to 7.6.

If the pH is above 7.6, free chlorine residuals of at least 0.75 to 1.2 ppm should be maintained.

Chlorine gas: Chlorine is an extremely active element which is found in nature only in combination with other elements. It is manufactured as a gas and then is liquified and stored in steel cylinders. Chlorinators are used to withdraw it as a gas and introduce it into water for feeding as a solution.

Chlorine gas is not explosive or flammable. It is 2-1/2 times heavier than air. It has a characteristic penetrating and irritating odor. At normal temperatures, it is not corrosive when dry, but it is very corrosive in the presence of moisture. It is a respiratory irritant; exposure to high concentrations will cause death by suffocation. Its use in water treatment results in lowering of the pH of the water.

Chlorine gas is not commonly used in swimming pools because of the hazards involved, high first costs of facilities including separate housing with ventilation equipment, the need for special knowledge and care in using it, and the need for pH adjustment.

Sodium hypochlorite: Sodium hypochlorite, NaOCL, is obtained as a solution containing 3 to 19 percent available chlorine. The familiar household laundry bleaches usually contain about 15 percent available chlorine. If obtained in bulk tank lots, they should be diluted at least in half to minimize loss of strength with time. Sodium hypochlorite solutions can be applied "full strength" but preferably should be diluted to 1 or 2 percent and then applied by positive displacement type chemical feed pumps. The solutions are alkaline and increase the pH of the water being chlorinated.

Sodium hypochlorite is by far the most commonly used disinfectant for public swimming pools in Michigan. The reasons for this include its proven effectiveness, its ready availability, the small amount of handling necessary, and the simplicity and low maintenance of the feeding system.

Calcium hypochlorite: Commercial high test calcium hypochlorite, $Ca(OCl)_2$, contains 70 percent available chlorine. It is produced in powder, granular, and tablet forms and is easily shipped and stored. It retains its strength for a year or more under normal storage conditions.

It is used for swimming pool water disinfection preferably by dissolving it in water in a corrosion resistant container, forming a 2 or 3 percent solution and applying the solution by a positive displacement type pump. One difficulty is that calcium carbonate (lime) precipitate also forms, in the solution container as a sludge and in the feeder and tubing as a deposit which may clog them and stop the flow.

Feeding methods such as dumping the dry chemical directly into the pool water, putting it in surface skimmer baskets, or hanging a container of it in the pool should not be used. The distribution of chlorine in the pool is uneven and inadequate, the lime precipitate causes cloudiness of the water, the concentrated chemical can corrode metal and discolor the pool bottom, and children may swallow undissolved tablets.

WARNING

Calcium hypochlorite is relatively stable under normal conditions, but it is a powerful oxidizing agent. Contact with heat, friction, moisture or a variety of materials such as oils, grease, paints, solvents, beverages or fertilizers may result in combustion. When heated, the chemical emits toxic fumes and may explode. It can cause severe irritation of the skin and is highly toxic when inhaled or ingested.

Precautions in its handling and use are extremely important. It should be stored in the original container, with the warning label clearly visible, in a cool, dry, clean place separated from flammables and out of reach of children. It must be covered and should be handled only with <u>clean</u>, <u>dry</u> utensils reserved for that purpose. It should never be mixed with anything except water. If spilled, it should be flushed with water; in case of fire, it should be quenched only with water.

<u>Cyanuric compounds</u>: Sodium dichloro-s-triazine trione or sodium dichloroisocyanurate, potassium dichloro-s-triazine trione or potassium dichloroisocyanurate, dichloroisocyanuric acid, and trichloro-s-triazine trione or trichloroisocyanurate are white, crystalline, strongly oxidizing materials classed as "available chlorine" organic compounds.

The aqueous solution of each results in the controlled release of chlorine and the formation of cyanuric acid. Studies indicate that the cyanuric acid (a) does not alter the type of chlorine residual obtained, (b) stabilizes or prolongs the chlorine residuals, and (c) somewhat inhibits the disinfection process, producing less bactericidal activity than without cyanuric acid. A concentration of 25 mg/l of cyanuric acid in swimming pool water is considered necessary for the stabilization of chlorine in the presence of sunlight. Higher levels are not considered to be more advantageous.

The Michigan Department of Public Health approves the use of cyanurates in the treatment of water at public swimming pools under the conditions listed in Department Letter No. 34 - 3. It provides that (a) cyanuric acid may be applied manually to condition the water, (b) the chlorinated cyanurates which may be used are the four listed above, (c) the chlorinated cyanurate shall be dissolved in water and the solution applied with a positive displacement type chemical feeder, (d) free chlorine residuals of at least 1.0 to 1.5 mg/l and a pH of 7.2 to 7.6 shall be maintained, and (e) the cyanuric acid level shall be tested at least weekly and shall not exceed 200 mg/l and preferably should not exceed 100 mg/l.

WARNING

Chlorinated cyanurates are strong oxidizing agents, both in the dry and dissolved states. Contact of dry chlorinated cyanurates with easily combustible material such as oil, grease, sawdust, and floor sweepings may cause such materials to burn and therefore should be avoided. They must be stored in a clean, dry, well ventilated place, away from flammables and heat, and out of the reach of children. They should never be mixed with anything except water. In case of spillage or accidental decomposition, they should be flooded with water. READ THE LABEL.

Chloramines: When chlorine is added to water containing natural or added ammonia, the chlorine and ammonia react to form combined available chlorine compounds or "chloramines." These compounds are much inferior to free available chlorine for water disinfection. With the same contact time, 25 times as much chloramine as free available chlorine is necessary to produce the same bacterial kill.

When enough more chlorine is added, the ammonia nitrogen is destroyed, and free available chlorine is formed. This process of adding enough chlorine to produce and maintain free available chlorine residuals is known as "free residual chlorination." It is the proper chlorination process for swimming pool water disinfection.

Because ammonia reacts with chlorine to form weak, slow acting chloramines, it should not be used in any form for swimming pool water treatment. Ammonium alum and sulfamic acid should not be used for that reason.

Control of chlorination: When chlorine is applied to disinfect swimming pool water, several factors influence its effectiveness. Substances from the air and from the swimmers exert chlorine demands to use it up. Direct sunshine dissipates it. Any free chlorine residual decreases with time. An increase in water temperature accelerates these actions.

Control of the chlorination process is based on (a) testing residual chlorine and (b) adjusting the chlorine feed rate accordingly. The water should be tested before the swimmers enter the pool and frequently enough thereafter to detect significant changes in the chlorine residual. Water for testing should be collected from the pool itself, at various points near swimmer activity, away from the pool water inlets.

Factors affecting disinfection: The bactericidal efficiency of chlorine in swimming pool water is dependent on several factors. Chief among them are (a) type of chlorine residual, (b) pH, (c) concentration of chlorine-consuming substances, (d) temperature, and (e) time of contact.

Free available chlorine is a much more effective disinfectant than combined available chlorine. Twenty-five times as much combined chlorine as free available chlorine may be needed to produce a 100 percent bacterial kill in the contact time. Using the same amounts of combined available chlorine and free available chlorine, combined available chlorine may require 100 times as long to produce the 100 percent bacterial kill. Free available chlorine, however, is more unstable and lasts a shorter time.

OTHER HALOGENS

The halogens are closely related elements: fluorine, chlorine, bromine and iodine. They are the most active nonmetals. Under standard conditions, fluorine and chlorine are gases, bromine is a liquid, and iodine is a solid. Fluorine is the best oxidizing agent and displaces all other halogens; chlorine is second in relative activity and displaces bromine and iodine; bromine is next and displaces iodine only; iodine is last and lacks the ability to displace any other halogen. All halogens are bactericidal. All except fluorine have been used for swimming pool water disinfection.

Bromine: Bromine has proven to be an effective swimming pool water disinfectant, but it has not had as widespread use as chlorine because of higher costs.

Brominated swimming pool water should have a bromine residual of at least 1.0 to 3.0 parts per million and a pH of 7.1 to 7.5.

At room temperature, bromine is a dark red, heavy, highly corrosive, fuming volatile liquid. It has a sharp, harsh, penetrating odor. If spilled on the skin, it produces severe burns. The vapors, even in low concentrations, are highly irritating and painful to the respiratory tract. Better equipment for handling and applying liquid bromine will be needed before it will be approved for use in Michigan.

Bromo-chloro-dimethyl hydantoin, a patented chemical compound with the trade name of Di-Halo, is a bromine chemical in a stable, solid form. The feeding system depends on controlled solubility rates of the chemical "sticks" in flow-through feeders. It is safe and simple to use.

Iodine: Of the four halogens, iodine has the highest atomic weight, is least soluble in water and reacts least readily with organic materials. In solution, it has the distinct advantages of being the most stable and longest lasting. These and other characteristics have stimulated interest in the use of iodine for swimming pool water disinfection. Studies related to its suitability for that purpose are in progress but have not yet resulted in its acceptance in Michigan.

ATHLETES FOOT (DERMATOMYCOSIS OR EPIDERMOPHYTOSIS OF THE EXTREMITIES)

It is possible for disease to be transmitted from one pool user to another, and the possibility of such transmission is increased when the pool is dirty, when the bathing load is high, when infected persons are using the pool, and when improper disinfection levels are maintained.

Athletes Foot (Dermatomycosis or Epidermophytosis of the Extremities)

Athletes foot is a ringworm type of infection caused by a parasitic fungus, the spore of which is spread by those infected by the disease. This disease is not spread through swimming pool water but by means of the pool decks, locker rooms, shower rooms, and other areas where the bare foot comes in contact with surfaces that have previously been contamined by the feet of an infected person.

Athletes foot is best controlled by properly washing and disinfecting locker room floors and benches, the shower and toilet room floors, steps, walkways, and the pool decks. The individual himself can be instrumental in preventing this disease by practicing good foot hygiene, such as thoroughly drying the feet, especially between the toes, with a clean towel; using clean socks and applying a fungicide specifically for athletes foot.

Ear Infections

Organisms causing ear infections are not particularly communicable via clean water, i.e., water containing proper residual of chlorine or other disinfectant. However, they can be transmitted by poor hygienic practices such as the use of a common towel.

An important factor in the incidence of ear infections is that the environment of the swimming pool water will activate an otherwise dormant infection, thereby producing clinical symptoms. For this reason, divers and underwater swimmers, who may be so predisposed, are especially prone to developing a resurgence of such ear infections.

Ear plugs are not effective in preventing ear infections but other factors may justify their use.

Eye ailments

Eye ailments represent the majority of medical complaints associated with swimming pools. However, many of these conditions are not actually infections but are irritations. Eye irritation can be caused by too high a pH, too low a pH, the tidal action of the water upon the eyes, and the individual's degree of sensitivity to fresh water and the chemicals used in the pool, as well as the length of time the bather stays in the swimming pool water. High disinfection levels are often blamed for eye irritations actually due to these other factors, as demonstrated by objective tests employing concentration levels far in excess of recommended limits.

Some persons may be concerned regarding the possibility of becoming infected with the gonococcus organism in the form of an ophthalmia. It is highly improbable, if not impossible, that this infection can be transmitted in this fashion. The gonococcus organism is extremely frail and its survival in an unfavorable environment, such as swimming pool water, would be of extremely short duration. There is no instance on record of gonorrheal ophthalmia being contracted in this manner.

Gastro-Intestinal Infections

The enteric group of diseases can be considered as truly waterborne. This group includes the Salmonellae, including the typhoids, the dysenteries, and various diarrheal infections. Gastro-intestinal organisms are hardy and there has been epidemiological evidence incriminating swimming pools in the transmission of such diseases. However, a properly maintained and regulated pool greatly diminishes, if not entirely eliminates, the possibility of such infections.

Granuloma

Granuloma is a condition caused by living organisms such as bacteria, fungi, or helminths; chemical agents; or physical agents. Granuloma occurs as a rounded or oval, pedunculated, mushroom-like tumor which springs up at the site of a secondarily infected injury or at the edge of a wound. This condition may occur on any part of a cutaneous surface.

Swimmers and bathers have been known to contract granuloma from swimming pool water. In some cases, the granuloma occurred at the site of what appeared to be an insignificant abrasion or scratch.

The possibility of contracting granuloma is reduced when the factors responsible for this condition are properly controlled. Specifically, maintain the pool water at a disinfection level which will destroy bacteria and fungi; remove physical agents which could be instrumental in causing or aggravating this condition, such as rough surfaces on the pool bottom and sides, sharp edges or other injury-producing conditions in the locker room, shower room, or pool deck area; and maintaining the chemical agents in the pool water within proper limits.

Plantar Warts

Warts are caused by a virus and are only slightly communicable. Plantar warts are warts that are on the plantar area of the foot. A person's contracting plantar warts may depend more upon the susceptibility of the person rather than on the communicability of the virus. Some authorities are convinced the susceptible will become infected regardless of the care taken to avoid contact with the virus.

The best preventive measure an individual can use to avoid becoming infected with plantar warts is to practice good foot hygiene.

Upper Respiratory Infections

Bacteria-producing respiratory infections are frail and will not survive long in an unfavorable environment, such as swimming pool water. As with ear infections, however, a person predisposed to respiratory infection may aggravate a resurgence of such infection by being in the water.

Viruses causing upper respiratory infections are more viable and are usually contracted through direct person-to-person contact.

Foot Baths

Foot baths are not effective in the control of foot infections and may even increase the chance of infection. The users of foot baths may develop a false sense of security and therefore neglect good foot hygiene, which they otherwise would have practiced if it had not been for their use of the foot bath.

Wading Pools

The wading pool is an item that is often overlooked as a possible source of disease and infection. The usual thought is that only swimming pools can transmit disease and infection and the wading pools cannot, because they are "only little puddles of water in which children play around." This is not so and it should be realized 12 inches of water may be a wading pool to an adult, but it is a swimming pool to a small child and is subject to the same safety hazards and contamination. Therefore, the wading pool should receive at least as much attention as the swimming pool.

Proper care of a private wading pool requires measures quite similar to those practiced at public wading pools, which are carefully engineered, operated, and supervised to reduce health and accident hazards to a minimum. The water in these pools is kept in satisfactory condition by being recirculated, filtered and disinfected continuously while in use. Personal cleanliness is required of the users of the pool. Sanitation and operation are checked frequently by the health department.

For a family wading pool, especially the portable type, equipment for circulating and filtering the water is expensive and is usually impractical. The best compromise that will reduce the chance of infection is to change the water often enough to keep it looking clean, and to add disinfectant before and during use. One should avoid submerging the end of a fill hose in the pool water, because under certain circumstances, the pool water could be siphoned into the pipes and contaminate the family drinking water. Construction and drainage of a permanent wading pool should be in accordance with the local plumbing code.

The following suggestions on the care of private wading pools should be followed in order to reduce the chance of accidents and the spread of disease:

1. The use of the pool should be restricted, if possible, to the members of the family. If playmates are allowed to share the pool, make certain that they are in good health. Do not overload the pool. Keep in mind that the person maintaining the pool has a legal liability as well as a moral responsibility for its condition and safety.

2. The water in the pool should be kept clean. Dirt and body washings in the water prevent the disinfectant from reaching microorganisms to destroy them. Make sure only clean apparel is worn by the users of the pool and their bodies, especially feet, have been cleansed. The frequency of complete water change required will depend on the rate at which dirt gets into the water and also on the degree of control maintained over the users of the pool. Each time the pool is emptied, it should be subjected to a thorough cleaning, prior to refilling.

3. Hot water may be added to the pool if the water is very cold. Children should not be allowed to stay in the pool so long at a time that they become seriously chilled, lowering their resistance to infection.

4. Metal and glass objects, soap, foodstuffs, pets, leaves, etc., tend to cause accident hazards or to use up the disinfectant, and should be kept out of the pool.

5. To reduce contamination of the pool water, a disinfectant such as household laundry bleach should be added to it. The bleach preferably should be diluted first, but it may be used without dilution if it is handled with care. It should be added about one hour before the pool is used and hourly during the period of pool use.

The table below shows the volume of water in wading pools and the quantities to use of a suggested diluted solution OR of undiluted bleach. For sizes not listed estimate from the nearest size in the table or from the pool volume.

The quantities are for each one foot of water depth. For example, for two feet of water depth, use twice the amount shown. For one-half foot of water, use one-half the amount shown.

RECOMMENDED QUANTITIES FOR DISINFECTING PRIVATE WADING POOLS*

Dimension of Pool: Round, dia.	Dimension of Pool: Square side	Gallons in Pool per Foot of Depth	Quantity of Diluted Solution**: Add 1 Hr. Before Use	Quantity of Diluted Solution**: Add Each Hour	Quantity of Undiluted Bleach: Add 1 Hr. Before use	Quantity of Undiluted Bleach: Add Each Hour
3 feet	2-1/2 ft	50	1 pint	1/2 cupful	1 tbsp.	1 tsp.
4 feet	3-1/2 ft	90	1 quart	1 cupful	1 ounce	2 tsps.
5 feet	4-1/2 ft	150	1-1/2 qts	1-1/2 cupfuls	1-1/2 ozs	2 tsps.
6 feet	5 feet	200	2 quarts	1 pint	1/4 cup	1 tbsp.
7 feet	6 feet	280	3 quarts	1-1/2 pts	2-1/2 ozs	4 tsps.
8 feet	7 feet	380	1 gallon	1 quart	3 ozs	5 tsps.
9 feet	8 feet	480	5 quarts	2-1/2 pts	3-1/2 ozs	5 tsps.
10 feet	9 feet	600	6 quarts	3 pints	1/2 cupful	1 ounce

(3 teaspoonfuls (tsps.) = 1 tablespoonful (tbsp.); 2 tablespoonfuls = 1 oz; 8 ozs = 1 cupful; 2 cupfuls = 1 pint; 2 pints = 1 quart; 4 quarts = 1 gallon)

*This table is based on the initial application of one quart of the diluted solution for each 100 gallons of water in the pool; or 1 fluid ounce of 5-1/4% household laundry bleach without dilution per 100 gallons; or 4 parts per million (ppm) of chlorine.

** To prepare this diluted solution, add one-half cupful of 5-1/4% household laundry bleach to about one gallon of tap water in a plastic pail or other corrosion-resistant container.

These quantities are approximate. They should be verified by use of a reliable chlorine test kit to maintain residual of 0.4 to 1.0 ppm while the pool is in use.

Computing Mixtures or Dilutions

To determine the relative quantities of solutions of different concentrations which should be mixed to obtain a specified concentration, draw a square or rectangle and label the upper and lower left-hand corners with the larger and smaller known concentrations respectively. Be sure both values are expressed in same units such as percentages or parts per million, etc.

Place the figure representing the desired concentration of the resulting solution or mixture in the center of the square.

Subtract (in appropriate directions) and enter the difference between the upper left figure and center figure in the lower right-hand corner; enter the difference between the center figure and the lower left figure in the upper right-hand corner.

These right-hand figures represent the number of parts of the two ingredients which should be mixed to secure the desired concentration. The value in the upper right-hand corner refers to the ingredient noted in the upper left-hand corner, and the lower-corner values similarly are related. The sum of the two right-hand numbers is the denominator of the fraction by which the total desired quantity should be multiplied, to determine the quantities (same units) of each ingredient to be used. Not the following example:

How many gallons of 10% sodium hypochlorite will be required to make 105 gallons of 8% sodium hypochlorite, by mixing with an appropriate quantity of 5% sodium hypochlorite solution?

(Given) 10%		3 parts (unknown)
	8% (Desired)	
(Given) 5%		2 parts (unknown)

10 - 8 = 2, and 8 - 5 = 3; 3 + 2 = 5; $\frac{3}{5}$ x 105 = 63 gal. of 10%.

Algae Control

Algae are varied colored, microscopic plants which appear commonly in outdoor pools and occasionally in the indoor pool waters. Growth occurs either in the free floating variety, or the clinging form which grows on pool surfaces.

Algae are not considered responsible for human diseases. Their presence in swimming pools is objectionable, however, because they:

a. may cause the pool bottom, sides and deck to be slippery;
b. are unsightly and may cause the pool water to be turbid and/or colored;
c. create a high chlorine demand;
d. reduce filter runs;
e. may foster bacterial growth;
f. may be responsible for odors.

Proper design of a swimming pool can assist greatly in the prevention of algae growth. Features of particular significance in this regard include suitable water disinfection and filtration facilities, multiple inlets for good circulation of water, smooth surfaces for the pool structure and deck, and shading from the sun.

Good pool operation is essential for the prevention of algae growth. The pool treatment facilities should be operated continuously, the water should be filtered properly, adequate chlorine residuals should be maintained, and high pool water temperatures should be avoided. The pool walls and bottom should be kept smooth and in good repair and should be brushed and vacuumed frequently. Pool decks and walkways should be kept cleaned and properly drained. Frequent scrubbing is advisable.

Outdoor swimming pools should receive "shock treatment" frequently, generally at least weekly, for the prevention of algae growth. This can be accomplished by increasing rapidly the chlorine application to obtain a free chlorine residual of 5 to 10 ppm. This must be done during nonswimming hours, such as at night, and the pool should not be used again until the clorine residual has decreased to normal.

Removal of algae growth is much more difficult. A sudden rise in pH of the pool water commonly accompanies algae growth and is a useful warning signal before it can be seen. "Shock treatment" followed by pool brushing and vacuuming may be enough to eliminate it. Where large growths have accumulated, it may be necessary to drain the pool and scrub all exposed surfaces with a 200 ppm chlorine solution. This solution can be made by adding 1/8 (1 ounce) of household bleach to 2 gallons of water.

Copper sulfate also can be used as an algicide (but should not be used as a pool water disinfectant). It can be used for shock treatment, using doses of 5 to 10 pounds per million gallons of water. Overdoses, however, can discolor pool surfaces and swimmers' hair and suits.

The use of other chemicals such as quaternary ammonium compounds as algicides is not recommended, except when the pool is emptied for cleaning.

SELF-HELP QUESTIONS ON SWIMMING POOLS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List at least seven desirable characteristics of swimming pool disinfectants.

2. What is the preferred pH of chlorinated swimming pool water?

3. Why is chlorine gas not commonly used in swimming pools?

4. Should a container of calcium hypochlorite be hung in the pool?

5. Should bulk tank lots of sodium hypochlorite be diluted?

6. What materials can be mixed safely with calcium hypochlorite?

7. How often must the cyanuric acid level in public swimming pools be tested?

8. What is free residual chlorination?

9. What effect does direct sunshine have on chlorine?

10. Is free available chlorine significantly more effective than combined availabel chlorine?

11. Do bromine vapors irritate the respiratory tract?

12. What advantages does iodine have over chlorine and bromine?

13. Can athlete's foot be transmitted through swimming pool water?

14. Are ear plugs effective in preventing ear infections?

15. List at least five factors that can cause eye irritations in swimming pools.

16. Is typhoid fever a true waterborne disease?

17. What is granuloma?

18. What causes plantar warts?

19. Are foot baths effective in the control of foot infections?

20. Can household laundry bleach safely be used in wading pools as a disinfections?

21. How many gallons of 15% sodium hypochlorite will be required to make 100 gallons of 12% sodium hypochlorite by mixing with an appropriate quantity of 5% sodium hypochlorite solution?

22. What is "shock treatment" for the prevention of algae growth?

ENVIRONMENTAL CONSIDERATIONS AND RESTRICTIONS

Incorrect application of chemicals in water may involve serious hazards to man, wildlife, fish and desirable plant life. Consequently you must:

- select the correct chemical for a specific aquatic site and particular plant infestation,
- apply it correctly at recommended rates,
- observe the restrictions on use of the treated water,
- be aware of the adverse effects of incorrect use, and
- obtain permission if necessary from appropriate state or federal agencies.

The control of aquatic vegetation presents special problems, because:

- the water often has multiple uses,
- herbicides will not always remain where they are placed, and
- herbicides may kill plants other than those intended.

Consider all the uses of the water to be treated, including those far downstream. Read the label to determine that the chemical you choose is compatible with these uses.

Types of water uses to consider before applying chemicals include:

- human use, such as drinking, cooking and swimming: Few tolerance have been established for herbicide residues in such water. Copper sulfate has been established for herbicide residues in such water. Copper sulfate has been used for control of algae in drinking water for many years and is permitted at the concentration of 1 ppm copper ion. Limited residues of several other herbicides are permitted in raw drinking water. However, you should avoid contaminating any drinking water with any level of herbicide or other pesticide.
- livestock and wild animal use,
- irrigation,
- industrial uses, and
- fish production. Most aquatic herbicides are not toxic to fish or other animal life at the concentrations recommended for plant control. Notable

exceptions are Grade B xylene, acrolein and some solvents and emulsifiers in certain formulations of normally nontoxic herbicides. These should not be used in fisheries, or where the water treated with these herbicides could enter fishery waters. It is possible to use these herbicides for treatment of small plots, or for treatment of plant-infested marginal areas, with little hazard to fish. If given an avenue of escape, fish will leave areas where the herbicide is used.

Trout are especially susceptible to copper sulfate. Trout waters should not be treated with copper sulfate without consulting fish biologists.

Pesticides should not be used where they may have unintended affects downstream.

Application Rates

Correct application of chemicals to aquatic situations involves equipment calibration and calculation of appropriate water volumes or areas. Environmental hazard can result from the incorrect application rate.

Excessive application can cause:

- damage to fish, either from direct toxicity, or from lack of oxygen caused by an excessively rapid kill of plants. Bacterial contamination resulting from decay of killed fish might further contaminate downstream water supplies.
- the need for exclusion of humans and livestock from use of the water for a longer time than necessary, and
- water unfit for irrigation use.

SELF-HELP QUESTIONS ON ENVIRONMENTAL CONSIDERATIONS AND RESTRICTIONS

Now that you have studied this section, answer the following questions. Write the answers with pencil without referring back to the text. When you are satisfied with your written answers, see if they are correct by checking them with the text. Erase your answer and write in the correct answer if your first answer is wrong. Note that these questions are not necessarily those that are used in the certification examination.

1. List at least five types of water uses to consider before applying chemicals.

2. List at least three possible results of excessive pesticide application to aquatic situations.

UNITS AND CONVERSION EQUIVALENTS

1 acre = 43,560 sq ft
1 acre-foot (A-ft) = 43,560 cu ft = 325,872 gal = 2,720,000 lb of water
1 cu ft per second (cfs) = 450 gallons per minute (gpm)
1 cu ft = 7.48 gal = 62.4 lb of water
1 gal = 128 fluid ounces = 8.33 lb of water
1 part per million by volume (ppmv) = 1 gal per million gal of water
1 part per million by weight (ppmw) = 8.33 lb of chemical per million gal of water
1 ppmw = 2.72 lb of chemical per A-ft of water gal of liquid formulation required

$$= \frac{\text{lb ai required}}{\text{lb ai per gal of concentrate}}$$

$$\text{lb of dry formulation required} = \frac{\text{lb ai required} \times 100}{\text{\% ai in formulation by weight}}$$

(ai = active ingredient)

FORMULAS FOR HERBICIDE APPLICATION TO CHANNELS

cfs = cross section area in sq ft × average velocity in ft per second (fps)
Cross section area of rectangular channel in sq ft = average width in feet times the average depth in ft

$$\text{ppmv} = \frac{\text{gal of chemical} \times 1{,}000{,}000}{\text{cfs} \times 450 \times \text{minutes applied}}$$

$$\text{gal of chemical per cfs} = \frac{\text{ppmv} \times 450 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{Total gal of chemical required} = \frac{\text{ppmv} \times 450 \times \text{cfs} \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{ppmw} = \frac{\text{lb of chemical} \times 1{,}000{,}000}{\text{cfs} \times 3744 \times \text{minutes applied}}$$

$$\text{ppmw} = \frac{\text{gal of formulation} \times \text{lb ai per gal} \times 1{,}000{,}000}{\text{cfs} \times 3744 \times \text{minutes applied}}$$

$$\text{lb of chemical per cfs} = \frac{\text{ppmw} \times 3744 \times \text{minutes applied}}{1{,}000{,}000}$$

$$\text{gal of formulation per cfs} = \frac{\text{ppmw} \times 3744 \times \text{minutes applied}}{\text{lb ai per gal} \times 1{,}000{,}000}$$

FORMULAS FOR HERBICIDE APPLICATION TO PONDS OR LAKES

Volume of pond in cu ft = surface area in sq ft × average depth in feet
Volume of pond in A-ft = surface area in acres × average depth in feet

$$\text{Volume of pond in A-ft} = \frac{\text{volume of pond in cu ft}}{43{,}560}$$

$$\text{ppmv} = \frac{\text{gal of 100\% active ingredient}}{\text{volume in A-ft} \times 0.33}$$

Total gal of chemical required = A-ft × ppmv × 0.33

$$\text{ppmw} = \frac{\text{lb ai of chemical applied}}{\text{volume in A-ft} \times 2.72}$$

Total lb ai required = A-ft × 2.72 × ppmw desired

$$\text{Total gal of liquid formulation required} = \frac{\text{A-ft} \times 2.72 \times \text{ppmw desired}}{\text{lb ai per gal of concentrate}}$$

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Appendix[1]. Selected references for the identification of aquatic plants.

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