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ABSTRACT

In order to determine if the pH of archival storage boxes decreases over time, experimental research was performed by sampling 25 Hollinger, one cubic foot, archival storage boxes from the Kent State University (Ohio) Archives. Boxes chosen for testing were new, 5, 10, 15, and 20 years old. Each box was tested for pH value using pH pens and a cold extraction method, both in duplicate, to see if there was a relationship between pH value and age of archival box. Most of the 10 to 20-year-old boxes increased in acidity in comparison to their original pH values. A few of the 10 to 20-year-old boxes were still acid-free. All new and 5-year-old boxes were found to be acid-free. The average cold extraction pH value is 9.4 for new boxes, 9.0 for 5-year-old boxes, 6.5 for 10-year-old boxes, 6.9 for 15-year-old boxes, and 6.5 for 20-year-old boxes. A correlation was done using the cold extraction pH results from the 10 to 20-year-old boxes, which produced an r-value of -0.436, showing a negative correlation between time (age of storage box) and pH value. Data are presented in table form. Contains 15 endnotes and 10 references. (Author/DLS)

THE AGING OF ARCHIVAL STORAGE BOXES AS INDICATED BY pH

A Master's Research Paper submitted to the
Kent State University School of Library Science
in partial fulfillment of the requirements
for the degree Master of Library Science

by

Theresa M. Nawalaniec

April, 1998

ABSTRACT
In order to determine if the pH of archival storage boxes decreases over time, experimental research was performed by sampling twenty-five Hollinger, one cubic foot archival storage boxes from Kent State University Archives. Boxes chosen for testing were new, five, ten, fifteen, and twenty years old. Each box was tested for pH value using 1) pH pens and 2) a cold extraction method, both in duplicate, to see if there was a relationship between pH value and age of archival box. Most of the ten to twenty-year-old boxes did increase in acidity in comparison to their original pH values. A few of the ten to twenty-year-old boxes are still acid-free. All new and five-year-old boxes were found to be acid-free. The average cold extraction pH value is 9.4 for new boxes, 9.0 for five-year-old boxes, 6.5 for ten-year-old boxes, 6.9 for fifteen-year-old boxes, and 6.5 for twenty year old boxes. A correlation was done using the cold extraction pH results from the ten to twenty-year-old boxes, which produced an r-value of –0.436, showing a negative correlation between time (age of storage box) and pH value.

Master's Research Paper by

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I. INTRODUCTION

Acidity is a widespread problem encountered in libraries and archives because it causes brittleness of paper and is also destructive to other types of materials. The largest cause of paper acidity occurs in the paper manufacturing process itself due to alum which is used as a waterproofing agent and to the presence of lignin which is found in wood pulp.[1] Acidity of materials then increases over time mainly because of light exposure, atmospheric pollutants, temperature, humidity, and migration.

Both UV and visible light, as well as atmospheric oxygen, cause the formation of carboxyl groups which increase acidity in paper.[2] Two major atmospheric pollutants commonly found in urban areas are sulfur dioxide and nitrogen dioxide which can permeate books and form sulfuric and nitric acids respectively when combined with water.[3] These are strong acids which will form in a humid environment and cause further degradation of materials. In addition, a 10 degree Celsius increase in temperature causes the rate of acid-producing chemical reactions to at least double. Chemically, the main factor causing degradation of paper is the acid-catalyzed hydrolysis of cellulose, which is a depolymerization of the cellulose chain.[4] Unfortunately, acid also migrates from one material to another either by direct contact or by volatile transmission through the air.

There are several measures one can take to prevent or slow down the increase of acidity in materials such as: avoiding exposure to light, protecting the material from atmospheric pollutants, and controlling the temperature and relative humidity of the storage area of the material. Another specific method of combating acidity problems is the use of acid-free or buffered phase boxes, containers, and envelopes to store and preserve materials. Much research has been done regarding the increasing acidity of books and papers with time, and several pH studies of these materials have also been performed. However, it appears that few studies have been performed on the archival quality housing materials themselves.

Purpose of the Study

The purpose of this study is to determine how containers used for the archival storage of material perform over time. In other words, do acid-free and buffered storage boxes retain their original level of alkalinity or do they also age and become more acidic as does paper? If their pH does decrease with time, the boxes may contribute to the degradation of the materials they are supposed to protect.

Definitions of Terms

Alkalinity and acidity are measured by pH which is the negative logarithm of the hydrogen ion concentration of a substance. It is usually represented on a scale of 1-14. A pH of 7 is considered neutral. As pH values increase above 7, they indicate increasing basicity or alkalinity, and as they decrease below 7, they indicate increasing acidity. Since the pH scale is logarithmic, a one unit change in value indicates a 10-fold change in acidity or alkalinity.[5] For example, a pH value of 3 is ten times more acidic than a value of 4.

A fold test or corner-fold test is used to measure the brittleness of paper. The fold test is performed by manually folding over the corner of a piece of paper or a page in a book, first in one direction and then in the opposite direction for either a predetermined number of double-folds (usually three) or until the paper breaks. For example, paper that breaks within three or less double-folds could be considered brittle.

Limitations of the Study

This study was conducted using materials from the Kent State University Archives. Specifically, Hollinger one-cubic-foot storage boxes were tested, so the results may not be applicable to other types or brands of archival storage boxes or to boxes that are stored in other archives under different environmental conditions. The temperature and relative humidity (R.H.) of the archival storage room have been monitored since 1984, and the readings show that they are not constant. The readings fluctuate between 68 and 80 degrees Fahrenheit and 35 to 60% humidity. Temperature and relative humidity are difficult to control since fluctuations occur within the library building as a whole. These changes in humidity and temperature are due to whether or not the heating or air conditioning is working properly in the building, and when either one is on, the temperature of the archives cannot be controlled.

II. LITERATURE REVIEW

Hanus, Komornikova, and Minarikova[6] looked at how archival storage boxes of differing quality affected the pH of the materials stored within them over time. In this study, alkaline and acidic papers were kept either inside of different types of boxes or outside of a box altogether and then tested for pH changes after accelerated aging. It was found that changes in pH were minimal (a difference of 0.1- 0.2 pH units) with respect to the type of storage box or type of paper analyzed. The most significant change in pH involved alkaline paper left out of a storage box. After 24 days of accelerated aging, the pH of the paper was almost one unit less than it was before aging, but was still considered to be alkaline enough to withstand long term storage. This study suggests that the pH of a storage box has little effect on its contents, but materials that are not kept in a container will decline in pH value.

A study of the Harold B. Lee Library at Brigham Young University (BYU) was performed by Nickerson.[7] A stratified random sampling technique was used to select books from among the four main floors of the library. Each chosen book was tested for brittleness using the corner-fold test and acidity using a pH pen. The result of a Chi-square test showed that acidity and brittleness were related. Ninety percent of the papers found to be brittle were also acidic. And, of the pages which were only slightly acidic, none were found to be brittle. The acidity levels of these books at BYU correlated well with the levels obtained from studies at Yale and Syracuse University. However, brittleness levels at BYU were considerably lower than levels at Yale and Syracuse, which indicated that something more than pH was affecting brittleness. It was suggested that the low humidity of the area where BYU is located, compared to the humidity of the locations of Yale and Syracuse, could lead to less brittleness. Also the BYU collection has been housed in an air-conditioned building which provides more constant temperature and humidity.

In contrast, a survey conducted by Mijland, Ector, and Van der Hoeven[8] provided results that question the link between pH and brittleness. Archival records from three different collections and different time periods were selected and tested for fold number, the presence of tears or missing pieces, edge damage, discoloration, and pH. It was found that over 60% of the materials from 1850-1900 were brittle, while only 20% of the materials before 1850 and after 1900 were brittle. Surprisingly, the one collection that had a higher pH, in general, also had a much greater percentage of brittleness. These results suggested that acidity may not be related to brittleness. Although there was a slight correlation ($r = 0.10$) between brittleness and acidity, the authors felt that there was no direct causal relationship between the two measures.

In a second survey by the same authors, a correlation coefficient of 0.25 was obtained relating acidity and brittleness. One interesting result was that for the time period of 1880-1910, papers that broke sooner during the fold test also had a higher pH. There was much overlap of pH range for both good and poor quality paper, indicated by the fold test, which suggested that acidity did not indicate paper quality. Paper type was then characterized as smooth or fibrous. Brittleness was related to slightly lower pH values in fibrous paper and pH was lower for newer fibrous paper, compared to older fibrous paper. Brittleness and acidity were also related for smooth paper from the period of 1840-1860. However, smooth paper from 1870 broke at both high and low pH values. The conclusion was that paper quality is determined by decade and type of paper -- other aspects such as pH have little or no effect on the brittleness of paper.

The National Diet Library, Japan's legal depository, has conducted annual pH surveys since 1986.[9] Current popular Japanese monographs have been tested to determine the use of alkaline paper. According to their report, any material with a pH over 6.5 is considered alkaline. The results of the 1986 survey, which was conducted by sampling all incoming books during a one week period, showed that 44.5% of all tested monographs were alkaline. In 1990 the procedure was changed to taking a random sample of 600 of all Japanese books that were published in the previous year. This procedure was then used for following years. The results for books published in 1989 and 1990 were very similar to each other; 69.7% and 70.9% respectively were found to be alkaline. It is obvious that the use of alkaline paper has increased greatly since 1986. Books of research value from Keio University were also tested to see how they compared to the commercial and government publications of the national depository and about 85% were found to be alkaline. Since more alkaline paper is being manufactured, the problem of acidic materials should not be as prevalent in the future.

Research was done by Slavin and Hanlan[10] to determine what influence environmental factors such as heat, humidity, and exposure would have on the migratory degradation of paper. pH neutral paper was stored in a sealed chamber with degraded newsprint. Three sets of samples were used: one having direct contact with the newspaper, the second having a buffered interleaf between the neutral paper and newsprint, and the third having a neutral interleaf between the paper and newspaper. Each set contained four samples: one encapsulated in Mylar, one exposed on both sides, and one sealed on the receptor (neutral) side, and the last sealed on the initiator (newsprint) side. After five weeks of aging in the dark at different temperatures, cold extraction pH was determined using TAPPI (T-509) and was compared with pH values of the controls. Results showed that both higher temperature and higher relative humidity (R.H.) each independently caused a greater decline in pH value. The exposed controls that were kept under high R.H. showed greater acidic degradation, which might have been caused by volatile degradation products. No significant decline in pH was observed that could be attributed to contact with the acidic newsprint, which suggests that migration degradation occurred due to volatility, not by physical or chemical means resulting from direct contact.

A kinetic study was done by Arney and Chapdelaine[11] to determine empirical rate constants by looking at the influence of acidity as indicated by tensile strength and decrease in diffuse reflectance (yellowing) versus time. Both acidic and buffered materials (newsprint and 100% cotton paper) were subjected to accelerated aging (high temperature and R.H.). The study began with the premise that both an atmospheric oxidation process and an oxygen-independent process cause paper aging or degradation. Results showed that acidic (pH 4.5) paper degrades approximately ten times faster than buffered (pH 7.9) paper. The same experiments were also conducted under an inert atmosphere of nitrogen. Both rates of loss of tensile strength and yellowing of paper were slower under nitrogen than in atmospheric air for all pH values. Since both the oxidation process and the oxygen-independent process were found to be pH dependent, the conclusion was that aging will depend on pH regardless of which process is more influential in aging at room temperature. Results also showed that deacidification is an effective way of slowing the aging and degradation of paper.

III. METHODOLOGY

The methodology used in this study is experimental research. A purposive sample of one-cubic-foot, Hollinger, acid-free storage boxes was chosen from Kent State University Archives. These containers are used primarily to store paper materials of historical value and are kept in the dark to prevent light exposure. Since the possible increase in acidity of the boxes over time will be tested, a somewhat random sample of five boxes of each of the following ages was taken: new (as a control), five years old, ten years old, fifteen years old, and twenty years old. The sampling used in this study is not truly random since a smaller number of boxes were sampled compared to the suggested sample size for the given population, and since particular boxes were chosen based on their age, which greatly decreased the number of possible choices.

Two portions of each box were cut out from the inner flap of the bottom of the box. Gloves were worn during the sampling and testing processes so that skin oils transferred by handling would not alter the pH readings of the samples. The pH of each sample (two per box) was analyzed using two methods. The first method employed was surface pH using pH pens, which contain an indicator that changes color when applied to the paper. This method was done in duplicate on both samples from each chosen box. Two pens were used—each made by a different manufacturer (Linco and Light Impressions) and containing a different indicator. The pen method is very easy, quick, and non-destructive, but has the limitation of not being reliable for use on colored materials because of difficulty in seeing the actual color change of the indicator ink. Another limitation is that pH pens take longer for a color change to occur on coated or sized materials such as cardboard.

The second method performed was cold extraction pH, also performed in duplicate for each sampled box, according to TAPPI method (T-509 om-96) with the modification of mixing the cut sample with Type I reagent grade water in a Waring blender for 45-60 seconds.[12] This variation saved time by eliminating the need for the sample to stand for one hour before measuring pH. Ultra high purity nitrogen was passed through the samples while blending and until the pH value was measured in order to prevent the absorption of CO_2, which would cause a decrease in pH. The extraction method is more precise and accurate than the pH pens since it produces a precise pH reading within 0.1 pH units using an electrode and pH meter. The method also measures the pH of the entire sample, including the inner portion too, not just the surface as the pens do. Since the inner portion is also measured, cold extraction pH results are higher than readings from surface methods. Therefore, the extraction results cannot be directly compared to the surface pH measurements. Limitations of the extraction method are that it is more time consuming than surface methods and it is destructive to the material being tested.

The Hollinger Corporation manufactured and sold archival storage boxes in 3 different colors (brown, white, and gray) at different times. The manufacturer of the boxes was contacted to determine what changes were made in box components and pH during the time periods in which the boxes were manufactured. The purpose of this inquiry was 1) to determine if the different box color was indicative of different initial properties and more importantly, 2) to determine what the initial pH values were in order to compare them to the current values obtained from testing. The brown boxes, which were discontinued in 1989, had a minimum initial pH of 7.2. White boxes have a minimum pH of 7.5 and are still manufactured from kraft paper run with an alkaline paper sizing instead of alum. The currently manufactured gray boxes have a minimum pH of 8.5, are buffered with 3% calcium carbonate, are lignin and sulfur-free, and meet the specifications of ANSI Standard IT9.2.[13] The Hollinger Corporation usually uses TAPPI T-509 (cold extraction method) to determine the pH values of their archival storage boxes.[14] Since the cold extraction method was also used for the research in this paper, the results will be meaningful when compared to Hollinger's original pH values.

IV. ANALYSIS OF DATA

The Light Impressions pH pen results were somewhat surprising, as they were better than anticipated. Most of the older brown boxes ranging from ten to twenty years old showed a surface pH containing only some acid, which is quite good considering the age of the boxes (especially the twenty-year-old ones) and the fact that they were not buffered. Two exceptions were a ten-year-old and a nine-year-old box which both had a highly acidic surface pH (see table 3.) Two positive exceptions were a fourteen-year-old and an eleven-year-old box that both had a somewhat acid-free surface pH (see tables 2 and 3.)

The Linco pH pen results did not seem to agree with the Light Impressions results for the ten to twenty-year-old boxes. The Linco results indicated that the pH values of all the brown boxes were <6, but these results are questionable. As mentioned earlier in the methodology section, the color of the material being tested may prevent one from ascertaining the true color change. In this case it was difficult if not impossible to determine whether the pH was <6 or between 6 and 6.8. This observation demonstrates why a pH pen is not the best method for measuring surface pH on colored materials. A better surface pH method is TAPPI (T-529), which uses a flat combination electrode and pH meter so that the color of the material has no effect on pH results. The T-529 method is also non-destructive to materials.

Moreover, the pen determinations produced different results for each side of the samples. It may be that the components of the cardboard used for the boxes (two flat pieces of cardboard surrounding a corrugated portion) may have had different initial pH values. Another possible explanation for the difference in pH may be because one side of the cardboard was in contact with the contents of the box and the other was not. These differences seen in surface pH readings provide an additional reason why cold extraction pH is a better method than surface pH for analyzing archival boxes. As mentioned earlier, cold extraction measures the pH of the entire sample including the inner portion, not just the surface.

The cold extraction pH results for the new and five-year-old boxes showed that they were all well above their original, minimum pH values of 8.5 and 7.5, respectively (see tables 4 and 5). However, most of the brown boxes (ten to twenty years old) did show a decrease from their initial pH values of greater than or equal to 7.2, as was expected. Four of the twenty-year-old boxes had average pH values of <6.8 and one of them was borderline slightly acidic/acid-free with an average pH of 6.8 (see table 1). Three of the fifteen-year-old boxes had average pH values <6.8, while the other two were still acid-free with average pH >7 (see table 2). Three of the ten-year-old boxes had pH values <6.8, while one was acid-free (>7) and one was borderline slightly acidic/acid-free with an average value of 6.9 (see table 3). Only one sample (# 13, which was ten years old) out of fifteen had a highly acidic pH of 5.4.

Sample numbers 7, 10, and 11 (two fifteen-year-old boxes and one ten-year-old box) retained pH values that were close to their initial minimum pH of 7.2 (see tables 2 and 3). It was observed for some samples, which had a pH value very close to 7, that it took a long time for the pH meter to equilibrate. The long equilibration time was probably due to these samples having a low ionic strength or a low buffering capacity in combination with the low ionic strength of the high-purity reagent grade water used for this testing. For these samples, the readings started at a pH of near 7 and then became more stable at about 7.3 to 7.4. Berndt and Love,[15] who did cold extraction testing and reported that equilibration time may have a significant effect on the pH reading, also experienced this phenomenon. They too found that, in most cases, pH increased with time. This effect of equilibration time is not really addressed in TAPPI method (T-509 om 96). The method states to record the pH only after there has been no measurable drift in thirty seconds. In the testing done for this paper, it was found that a pH reading near 7 could be stable for thirty seconds and then still increase upwards, showing that time can be an important variable when determining pH values.

A correlation was done using all of the cold extraction pH values (for the brown ten to twenty-year-old boxes, including their original, minimum pH value of 7.2), versus time (age of storage box), and an r-value of -0.436 was obtained. This negative correlation showed that pH is inversely related to time (see chart I). The reason that the correlation is not greater is due to the low pH values of the ten-year-old boxes. A less likely possibility is that the fifteen and twenty-year-old boxes had abnormally high pH values.

Sample	#	pH Pen		Cold Extraction pH	
~20 yr. old		*Linco*	*Light Impressions*		CE pH Average
#1 - 1977	1	<6	some acid	6.7	
brown	2	<6	some acid	6.4	6.6
#2 - 1977	1	<6	some acid	6.5	
brown	2	<6	some acid	6.7	6.6
#3 - 1978	1	<6	some acid	7	
brown	2	<6	some acid	6.7	6.8
#4 - 1978	1	<6	some acid	6.4	
brown	2	<6	some acid	6.2	6.3
#5 - 1979	1	<6	some acid	6.2	
brown	2	<6	some acid	6.5	6.4
					6.5

Table 1

Sample	#	pH Pen		Cold Extraction pH	
~15 yr. old		*Linco*	*Light Impressions*		CE pH Average
#6 - 1983	1	<6	some acid	6.7	
brown	2	<6	some acid	6.9	6.8
#7 - 1984	1	<6	some acid	7.4	
brown	2	<6	some acid	7.4	7.4
#8 - 1984	1	<6	some acid	6.8	
brown	2	<6	some acid	6.6	6.7
#9 - 1984	1	<6	some acid	6.4	
brown	2	<6	some acid	6.7	6.6
#10 - 1984	1	<6	some acid	7.3	
brown	2	<6	some/acid-free	7.0	7.2
					6.9

Table 2

Sample	#	pH Pen		Cold Extraction pH	
		Linco	*Light Impressions*		CE pH
~10 yr. old					Average
#11 - 1987	1	<6	acid-free	7.2	
brown	2	<6	some acid	7.3	7.2
#12 - 1988	1	<6	some acid	6.3	
brown	2	<6	some acid	6.4	6.4
#13 - 1988	1	<6	high acid	5.4	
brown	2	<6	high acid	5.4	5.4
#14 - 1988	1	<6	some acid	7.0	
brown	2	<6	some acid	6.8	6.9
#15 - 1989	1	<6	high acid	6.6	
brown	2	<6	high acid	6.5	6.6
					6.5

Table 3

Sample	#	pH Pen		Cold Extraction pH	
		Linco	*Light Impressions*		CE pH
~5 yr. old					Average
#16 - 1993	1	>6.8	acid-free	8.9	
white	2	>6.8	acid-free	9	9
#17 - 1993	1	>6.8	acid-free	9.2	
white	2	>6.8	acid-free	9	9.1
#18 - 1993	1	>6.8	acid-free	9.1	
white	2	>6.8	acid-free	9	9
#19 - 1993	1	>6.8	acid-free	8.9	
white	2	>6.8	acid-free	8.9	8.9
#20 - 1993	1	> 6.8	acid-free	8.9	
white	2	> 6.8	acid-free	8.8	8.8
					9

Table 4

Sample	#	pH Pen		Cold Extraction pH	
		Linco	*Light Impressions*		CE pH
New Controls					Average
#21 - 1997	1	>6.8	acid-free	9.5	
gray	2	>6.8	acid-free	9.4	9.4
#22 - 1997	1	>6.8	acid-free	9.6	
gray	2	>6.8	acid-free	9.4	9.5
#23 - 1997	1	>6.8	acid-free	9.5	
gray	2	>6.8	acid-free	9.5	9.5
#24 - 1997	1	>6.8	acid-free	9.5	
gray	2	>6.8	acid-free	9.2	9.4
#25 - 1997	1	>6.8	acid-free	9.5	
gray	2	>6.8	acid-free	9.4	9.4
					9.4

Table 5

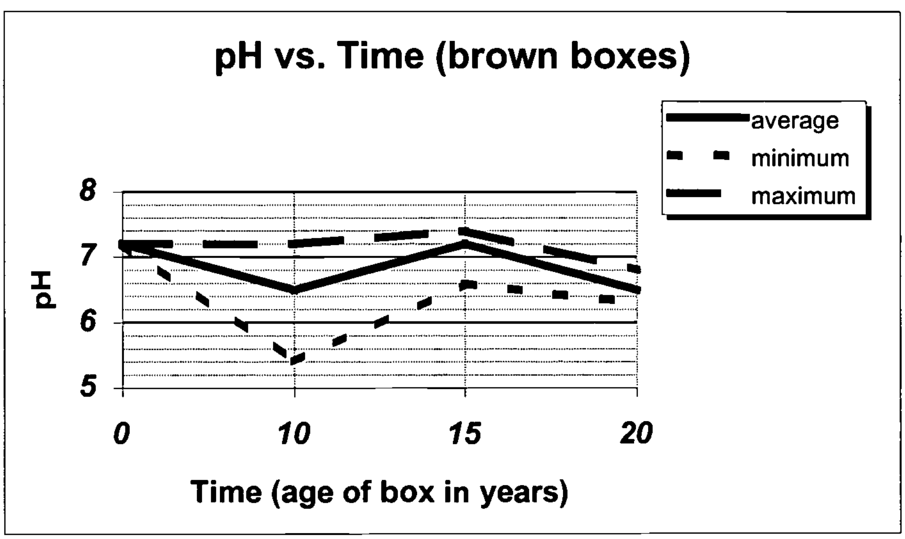

Chart I

V. SUMMARY AND CONCLUSIONS

The increasing acidity of paper materials is an important issue in today's libraries and archives and much research has been done in this area. An area that has not been well explored is the stability of archival storage boxes. In order to determine how the pH of archival storage boxes changes with time, twenty-five one-cubic-foot, Hollinger boxes were sampled from Kent State University Archives. The results obtained may not apply to other types or brands of storage boxes or to boxes stored in other archives. The boxes chosen for analysis were new (control), five years old, ten years old, fifteen years old, and twenty years old.

Using experimental research, the box samples were tested in duplicate for: 1) surface pH, using two different pH pens, and 2) cold extraction pH, using TAPPI test method (T-509 om-96). The second method is more accurate and precise than the first one since it gives pH readings within 0.1 pH units of the entire sample, not just its surface. Results of the testing showed that the new and five-year-old boxes were both acid-free and the ten to twenty-year-old boxes were slightly acidic in most cases. However, one box (ten years old) was found to be highly acidic. The average pH values from the cold extraction method are: 9.4 for the new, gray boxes, which had an initial, minimum pH of 8.5; 9.0 for the five-year-old white boxes, which had an initial, minimum pH of 7.5; and 6.5 for the ten-year-old brown boxes, 6.9 for the fifteen-year-old brown boxes, and 6.5 for the twenty-year-old brown boxes, which all had an original pH of at least 7.2 (see table 6). All of the cold extraction results for the brown boxes were correlated and an r-value of –0.436 was obtained showing that pH is inversely related to time as indicated by age of storage box.

	Minimum Initial pH	Tested Average pH
new	8.5	9.4
five-year-old	7.5	9
ten-year-old	7.2	6.5
fifteen-year-old	7.2	6.9
twenty-year-old	7.2	6.5

Table 6

In general, the pH values of the ten to twenty-year-old archival storage boxes did decrease over time. This increase in acidity of the boxes may be detrimental to the materials contained within them and may also continue to increase with time. However, there was no definite pattern or correlation relating age of storage box and pH for this limited sample size. Some boxes of each age were still acid-free, while others were found to be acidic. These observed differences in acidity may be due to: 1) what was contained in the boxes, 2) where the boxes were placed within the archives (such as near a heat source or near the ceiling, since heat rises) or, 3) differences in the boxes themselves when they were first received (for example, they might have come from different lots). It is extremely interesting that one ten-year-old box had a pH value that was approximately one pH unit and, in some cases, two pH units less than all of the rest, which means that it is ten to one-hundred times more acidic than all the other brown boxes that were tested. This one highly acidic box will be detrimental to the material contained within it, because of direct contact and migration, especially if the contents are less acidic than the storage box.

The results of this research have indicated that there is an increase in acidity of older storage boxes and that a small portion of these boxes are highly acidic. Therefore, it would be beneficial to replace the brown archival boxes with new gray boxes, which are acid-free and buffered. Performing a more extensive survey of the older boxes would be an interesting project. If more boxes were tested it would be possible to see what type of trend, if any, there might be regarding the pH of these archival storage boxes. One possibility for future research would be to look at what types of materials are housed in the boxes, and then determine the pH values, if feasible, of those materials, to see how they might have affected the pH of the storage boxes. The locations of the boxes could also be noted to determine if that had any possible influence on pH as proposed above.

ENDNOTES

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3. Ibid, 884.

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