Paper Deterioration:

Causes and Methods of Intervention

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In 1969, at the thirty-fourth annual conference sponsored by the Graduate Library School of the University of Chicago on the *Deterioration and Preservation of Library Materials,* Edwin Williams stated "Everything in library collections is deteriorating today, was deteriorating yesterday, and will continue to deteriorate tomorrow although we ought to retard the process." (p. 3). While a broad statement, it is no less true today than it was nearly 50 years ago. One of the most difficult issues libraries can face is how to protect the materials in their collections. R. Bruce Arnold (1997), Chair of the ASTM Paper Aging Research Program, indicates that quite literally "billions of books and documents made during the last century and a half are disintegrating before our eyes" (p. 15). They are already so brittle that their pages cannot be turned. But according to the Library of Congress, though paper deterioration remains a problem, thanks to years of scientific research it is no longer such a mystery. There is deeper understanding for both the causes of deterioration and the methods needed to slow its progress ("The Deterioration and Preservation of Paper", n.d.).

An important factor in the understanding of paper deterioration is to recognize its contributors. These contributors can be identified in three general categories: internal, environmental and use/handling. This paper will begin by examining each of those factors contributing to deterioration beginning with the internal factors.

Not all paper is created equally. There are reasons why paper made hundreds of years ago is in better condition now than paper made just forty or fifty years ago. Paper is made of cellulose, which is the insoluble substance that is main the component of the cell wall of plants

and vegetable fibers like cotton. Cellulose is made up of a repeating chains of glucose molecules. The length of these chains helps to determine the strength the paper. A long chain of cellulose produces a long fibered paper which is stronger and more durable than a short fibered paper. ("The Deterioration and Preservation of Paper", n.d.).

Prior to the middle of the 19th century most paper was made from cotton or linen cloth. These papers were made by craftsmen who produced them by hand. To seal these papers and allow them to hold ink they were coated with animal gelatins in a process called sizing. These animal gelatins were not harmful to the cellulose (Arnold, 1997, p.16). Chlorine did cause damage as papermakers learned they could make dirty and discolored rags look new again. Many eighteenth and early nineteenth century works were damaged by the chlorine residue (Poole, 1977, p. 165).

As demand for paper increased the process began to change. With the introduction and expansion of mechanized continuous papermaking, alternative approaches were introduced to keep up with the demand (Arnold, 1997, p.16). Rosin from pine trees was used to size printing papers rather than animal gelatins. Alum was necessary to set the rosin in the fiber to achieve the desired results. During this process, sulfuric acid is formed and the paper treated with this alum/rosin sizing retained that acidity. This increase in acidity is a significant internal contributor to the deterioration of paper (p.17). Another change in the papermaking industry that impacted the strength and longevity of the paper produced was the transition from the use of cotton and linen rags to wood. Early methods of grinding the wood used a rotating stone, but this retained all organic material from the wood, not just the cellulose. Chemical processes where then introduced to remove these other substances such as lignin. The most common process of the late 1800s and early 1900s was the sulphite pulping method which was acidic. So, during this time,

acidity of the paper produced was being increased by both the materials being used and manufacturing processes (p. 17).

A variety of environmental factors can affect the deterioration of paper whether it be in a library, archives, business or home. Temperature, defined by Millar and Roper as "the level of heat or cold in a substance, body or environment" (1999, p. 15) is the first of these environmental factors we will discuss. In general, paper will deteriorate more quickly in higher temperatures. This is due to the fact that most chemical processes are accelerated with an increase in temperature (p. 15). Banks (2000) asserts that a reduction in temperature from 77°F to 68°F could "increase by 2.4 times the time required for 'good quality' paper to lose half its useful properties" (p. 115). He also indicates that this could be even greater for paper that is already acidic.

Another key environmental factor is relative humidity. Relative humidity is the ratio of the amount of water vapor present in the air expressed as a percentage of the amount needed for saturation at the same temperature (Millar & Roper, 1999, p. 15). High relative humidity, especially when paired with high temperatures, can speed up deterioration. If the air is too dry, meaning relative humidity is too low that can also be damaging, particularly to paper that is already brittle (p. 15). Banks (2000) goes into greater detail of the complexities of relative humidity. He explains that it is not actually the humidity of the air that impacts deterioration but it is the equilibrium moisture content or EMC of the item itself, whether it be a book or piece of paper, that matters. Paper has the ability to take up and give off moisture depending on the relative humidity. As it is not practical to control the moisture levels of each individual piece of paper we can control relative humidity. It is important to note that frequent changes in relative humidity can be even worse than levels that are consistently a little high or a little low. Banks

indicates that the evidence is now growing to indicate that relative humidity as low as 30% can increase the life of paper (p. 116).

Light can have several detrimental effects on paper. It can speed up oxidation which causes it to break down faster. It generates heat, which as previously discussed can speed up the chemical processes that lead to deterioration. Ultraviolet light is considered to be the most harmful because it produces more radiation. Radiation in high levels can increase chemical deterioration. Both sunlight and fluorescent light contain ultraviolet light. These types of light should be controlled in the library environment as much as possible (Millar & Roper, 1999, p.18).

Paper deterioration can also be influenced by pollutants. These can be in the form of gases like sulphur dioxide, nitrogen dioxide, and hydrogen sulphide. The causes of pollution are even more numerous. Chemicals, car exhaust, cleaning products, paints, adhesives, and even the office photocopier can be sources of pollutants. These airborne chemicals are acidic. As they come into contact with materials in a library collection they can cause them to break down (p. 21).

A couple of final environmental considerations would be biological agents such as mold, insect, and even rodents. The spores that cause mold to grow are almost present in the air so is it nearly impossible to eliminate them complete (p. 25). In its active state mold produces enzymes that can both weaken and stain paper. (“Emergency Salvage of Moldy Books and Paper”, 2012). Many insects are attracted to the materials in library collections such as sizes, adhesives and starches. Silverfish, cockroaches and psocids are among the most pests to be found in a library. While these insects might not be attracted to the paper itself they can still be very damaging to that paper. This damage is cause by feeding, tunneling, nesting and their bodily secretions

("Integrated Pest Management", n.d.). Finally, rodents can eat paper or use it for nesting materials. Much like insects their bodily secretions can also be damaging to paper (Millar & Roper, 1999, p. 27).

The third factor to address in the causes of paper deterioration is use and handling. Often people can pose one of the greatest dangers to library materials whether intentionally or unintentionally. This includes library staff, volunteers and patrons. There are a variety of practices that lead to the deterioration of library materials. Levels of mishandling can vary considerably from intentional acts of vandalism to carelessness that results in food or drinks being spilled on pages of a book. This would also include writing or highlighting in book or writing on archival documents. It could be much simpler, like turning down the pages of a library book, rather than using a bookmark or licking fingers before turning a page. There are also damaging practices that can be perpetrated by staff and volunteers. Improper shelving conditions put undue strain on books. Poor retrieval and filing in archival collections can cause damage to individual pages. Inappropriate exhibit practices can expose paper to extreme conditions that cause deterioration. Finally, poor housekeeping practices can lead to infestation by rodents or insects which, as previously discussed, are a danger to collections (p. 28).

Now with a better understanding of what contributes to the problem of paper deterioration it becomes clear that these factors exist in a complex relationship in any library. The question then becomes one of what can be done to solve or at the very least mitigate these issues. The approaches to preserving these materials may take one of two courses. They will either retain the original format of the material or they could alter that format. We will first examine the methods of intervention that will retain the original format.

As previously indicated environmental factors such as temperature, relative humidity, light, pollutants, and vermin all take their toll on the well-being of paper based materials in a collection. By taking steps to control the environment in which paper based materials are stored it can slow the deterioration of those materials and extend their life. Temperature controls would be the first parameter to consider. If collections are maintained separate from its users, Banks (2000) suggests a target temperature of 62°-65°F but if users are present a target of 68°-70°F would be more appropriate (p.122). In a 1977 article for the Society of American Archivists former preservation officer of the Library of Congress, Frazer Poole (1977) asserted his opinions on the importance of temperature on the longevity of paper. He indicated that a new book could have its lifespan extended from 50 years at 72°F to as much as 400 years if stored at 32°F (p. 166). Temperature can be controlled with the use of sensors and thermostats that are typically integrated into most HVAC systems. Window air conditioners also provide an option when a full HVAC system is not a possibility (Banks, 2000, p. 131).

Relative humidity is also an important concern. Several factors impact relative humidity including regional climate, season and the nature of the building housing the collection. It is important to measure relative humidity regularly. The limits for relative humidity may be as high as 50% or as low as 30%. It appears that consistence is the most important thing. Fluctuations should of more than 3% should be avoided. But as previously noted some evidence does indicate that lower relative humidity is beneficial for the life of materials (p. 122). It is harder to control relative humidity than temperature, especially in more humid parts of the country. In some cases, the use of portable humidifiers or dehumidifiers may be necessary to keep within the acceptable range (p. 131).

Light damage can be avoided in a variety of ways. In an ideal world, there would be no windows in areas housing collections. However, this is not always the case. Tinted or reflective glass can be used to reduce UV transmissions. Solar-control films can be utilized for existing windows but their life expectancy should be a consideration versus cost. Blinds can also be used as a cost-effective solution to accommodate users and control light. They do have some drawbacks as someone must remember to close them at the appropriate times or they fail to serve their purpose. UV filtering sleeves are available to reduce the UV from fluorescent light but they can be costly. Another option is to turn lights off in any area where they are not in use specifically in a closed stacks environment (p. 132).

An HVAC can also be helpful in controlling pollutants in the environment. The system contains various filters that clean the air as it passes through removing pollutants that would otherwise reach collection materials (p. 130). Many of the suggestions listed above will also impact the presence of biological agents. By controlling temperature and relative humidity it also reduces the risks of mold and pests as it removes their ideal environment. Inspecting all materials before they are bought into the collections area is also helpful in prevent an infestation (Millar & Roper, 1999, p. 27).

A separate factor related to deterioration previously discussed was use and handling. According to Poole (1977):

> Unfortunately, archivists and librarians, as well as users, too often damage, destroy, or simply permit the destruction of the very items they are expected to preserve. Improper storage and handling resulting from ignorance, indifference, carelessness, and sheer neglect are the basic causes of far more damage than most custodians would care to admit (p. 166).

In order to protect materials from damage, either from willful destruction or carelessness, a variety of steps can be employed. Staff and volunteers should be educated on the proper way to handle materials, so they in turn can help to educate patrons. Materials should be stored appropriately, particularly those in fragile condition. Guidelines should be provided for the safe use of materials ((Millar & Roper, 1999, p. 29).

All of the approaches discussed above in regards to the physical environment in which collections are maintained and the handling practices for those collections are designed to prevent or slow the process of paper deterioration. However, due to the highly acidic nature of many collections, it is a process that cannot be prevented. The embrittlement of library collections has been of major concern for many years and continues to be so today. A Library of Congress sampling as early as 1972 indicated that up to 6 million of their 17 million volumes were in the advanced stages of deterioration. In the same timeframe, the New York Public Library approximated that 50% of their collection is quickly reaching that same point (Poole, 1777, p. 164).

The process of deacidification was introduced to help combat this issue of acidity and embrittlement. The process neutralizes acidity by saturating materials in an alkaline solution with the goal of not only neutralizing the acids but depositing an alkaline substance that would create a reserve (Zervos & Alexopoulou, 2015, p. 2668). The aqueous process for deacidification begins with the materials being washed in water for 1 to 2 hours to remove as much of the soluble acidity as possible. This also allows for more of the alkaline reserve to be absorbed by the paper. This form of treatment is preferred for loose sheets of paper. Bound books should be unbound into loose leaves before treatment (p. 2870). The aqueous process had a couple of limitations in that it could not be utilized for items with water-sensitive inks and could not be

used for mass deacidification. A non-aqueous process then evolved utilizing organic solvents. This allowed for the development of several mass deacidification systems. There are three major types of systems: liquid solutions, liquid suspensions and gas phase methods. There is no method or specific system that is appropriate for all types of materials and most systems have their own specific drawbacks to treatment (p. 2874).

While there are several mass deacidification systems in use in the United States and around the world only two will be addressed in detail here. The Bookkeeper system is currently utilized by the Library of Congress for their mass deacidification needs. The Bookkeeper spray uses insoluble magnesium oxide that is appropriate for bound and unbound materials with a process taking about 2 hours per batch (p. 2876). Since the inception of their 30-year mass deacidification initiative in 2001 the Library of Congress has processed 3.78 million volumes and over 10 million sheets of manuscript materials in their collections (Mass Deacidification, n.d.). The Wei T'o System, developed by Richard D. Smith and utilized until 2002 by the National Library and the National Archives of Canada, uses methoxy-magnesium methyl carbonate as the deacidifying agent and methanol and perfluorocarbons as the solvent systems. It is now available as a spray for use in workshops on individual items (p. 2876). The Wei T'o System is a four-step process. Books are selected and evaluated. They are then vacuum dried for 36 hours to avoid exposure of the magnesium alkoxide to water. The deacidification then takes place which is followed by a period of up to 48 hours to recondition the item to its normal surroundings (Grimard, 1994, p. 676). This system was used by the National Archives of Canada to treat books but not archival materials with an average of 162,000 books treated per year. It is important to note that mass deacidification can be a costly endeavor to embark upon. The National Archives estimates that the cost of operating the system from 1991 to 1992 was nearly

$300,000(Canadian). For the same year, they estimate their average cost per book treated was $7.10 (p. 677).

One final method of deacidifying is interleaving. It consists of placing an alkaline sheet of paper that contains calcium carbonate in contact with acidic paper. It is an inexpensive and easy method that is not damaging to collections. This process can be used for bound book but care should be taken not to damage the spine with the weight of the extra pages (Zervos & Alexopoulou, 2015, p. 2873).

In many situations, it not possible to preserve library materials in their original format. They can be heavily used, damaged or weak. When the information in these items is in danger of being lost, it becomes important to create a copy. Judith Fortson-Jones (1984) states very simply that there are no miracle cures. She suggests instead to uses the tools that are readily available, the photocopy and microfilm. While she is not a great proponent of the photocopy due to the major disadvantage it presents in the additional space needed to house the additional volume of paper created, it does present a cost effective and available option for items in peril (p. 85). She is a far more in favor of microfilm, stating

> we cannot afford to save every piece of paper, whether due to constraints of time or of money. So, in a way, microfilm *is* the present answer to at least one prayer. Silver halide microfilm, if properly processed and stored, is of archival quality, and thus preserves information at a great saving of space. In addition, it is actually a conservation tool which enables us more effectively to preserve those original items we do wish to keep in their original from by reducing damage from use (p. 86).

Microfilming represents a stable and cost-effective way to preserve deteriorating items. It has been used in some significant preservation projects such as the Brittle Books Initiative and the

American Newspapers Project (Hedstrom, 1997, p. 190). Estimated to last 500 years or more, microfilm far exceeds any other format in terms of its life expectancy. It also requires no special hardware or software for viewing (p. 194). Digitization is another way to preserve materials that offers some specific advantages. The quality of digital images is excellent and only continues to improve. It also allows for images to be accessed easily, even remotely (Conway, 2000). There are still some disadvantages to digital preservation as the technology is still evolving. With hardware and formats constantly changing the issue of long-term accessibly presents itself. There is also the concern that there is a lack of established standards for and protocols for digital preservation (Hedstrom, 1997, p. 191). All these factors should be considered when choosing the appropriate method for the task.

The deterioration of paper is not a new problem. We are not suddenly becoming aware of the issue. Williams (1970) notes entries in British periodicals as early as 1823 with mentions of the issue (p. 4). Due to the poor papermaking practices noted above the situation has become significantly worse as time has passed. But there have been some attempts to turn the tide. The mass deacidification projects undertaken by both the Library of Congress and the National Archives of Canada have made some important progress. In 1988 the National Endowment for the Humanities began a 20-year plan to microfilm 3 million books (NEH Timeline, n.d.). Then in 2007 the Library of Congress received a $2 million grant to begin a digitization project with a focus on brittle books called “Digitizing American Imprints” (Caterinicchia, 2007). These are just a few of the many projects underway around the country to combat this problem. But these are just small battles in a large war. And in the end Judith Fortson-Jones (1984) may have said it best when she simply stated “Do what you can” (p. 89).

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