

The Day the University Changed

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Introduction -- The Flood at Colorado State University

The largest water-related library disaster in U.S. history occurred at Colorado State University's (CSU) Morgan Library in Fort Collins, Colorado on July 28, 1997. This flood was caused by a series of summer rainstorms that began the day earlier, July 27—and lasted off and on for about 31 hours, culminating in a five-hour torrent that saturated the foothills surrounding Fort Collins with 10 to 14.5 inches of rainfall.¹ The arid soil in the surrounding hills quickly became saturated; the resultant rapid runoff flowed into low areas of the town and caused a river to swell its banks which led to five deaths in a mobile home trailer park near the University. The storm was characterized as a “100 year event.”

CSU was not unscathed. Runoff combined with detritus began to fill the below-grade floors of approximately one third of its campus buildings.² On the football field adjacent to the Morgan Library, pooled rainwater collected until a natural earthen berm gave way under the water's increasing weight and sent a wave of water and debris racing toward the library's newly-completed, below-ground addition. The water forced its way into the building through a basement window that exploded as a portion of the wall collapsed. The water filled the room to a depth of eight feet (more than two meters), completely submerging the stacks. Approximately 425,000 books consisting primarily of twentieth-century science books and journals were saturated by rushing water mixed with ceiling tiles and grime. The swirling water washed books from their shelves and knocked down some of the free-standing, baked enamel shelving. The force of the moving water actually forced several volumes up through the duct work of the building's air handling system and deposited them on the ground outside the building where they were discovered several days later lodged in the mud.

The Response

CSU responded to the crisis immediately by hiring a consultant to coordinate the simultaneous restoration of its 30+ damaged buildings, and President Albert C. Yates and his Administrative Council determined that the campus (which was between semesters when the disaster struck) would seamlessly resume operations without interruption. He planned to reopen the campus the following week and welcome students back for summer quarter to ensure the institution's fiscal as well as academic continuity. The University also hired a professional disaster recovery firm specializing in library recovery to address the problem of the Morgan Library's books. The campus-wide consultant, having no expertise in the recovery of library material, then invited me to consult with him on library conservation issues, an offer readily accepted.

My first reaction upon reaching the disaster site two days after the water had been pumped from the basement was one of surprise at how little damage had occurred to the town of Fort Collins proper, and then disbelief at the amount of devastation that had occurred specifically inside Morgan Library. Within 24 hours, flood waters were removed from Morgan Library's basement

with the use of portable electrical pumps. As the sodden collection sat exposed to air awaiting the next stages of recovery, the library's new, steel compact shelving was slowly destroyed by expansion of the swelling books. In places, swollen sets of journals performed gymnastic feats, arching away from their shelves a full 10 inches like silent, buckram-covered accordions. All electricity within the library was incapacitated by the sudden intrusion of water into the building, and the damaged central heating, ventilation, and air conditioning (HVAC) system remained inoperable for nearly a week.

The flood prompted Colorado Governor Roy Romer to expeditiously request Federal assistance. Within days President Bill Clinton declared Fort Collins a Federal Emergency area and initiated the involvement of the Federal Emergency Management Agency (FEMA). Aid was immediately administered to the residents of the damaged trailer park near the University, but a question arose concerning FEMA's fiscal responsibility to CSU. In Federal parlance, the formal definition of a "flood" is water overflowing the banks of a river. Since the CSU campus was affected only by rainwater running off the surrounding foothills, it appeared the University would not qualify for Federal assistance. Fortunately for all concerned, the University was adequately insured under State policies and this issue became, while intellectually challenging, a mute point.

The Packout

The packout was initiated by the disaster recovery firm specializing in library recovery. Arriving on-site, I observed the firm's temporary employees (temps) loading books into unlined, paperboard "banker's boxes" (15"x12"x10") that were subsequently moved to a conveyor belt assembled on the stairway connecting the basement with the library's ground floor. The boxes were tossed down onto this conveyor belt with a loud "thud" as though they contained frozen turkeys, and moved upstairs to the first floor where they were transferred onto two-wheeled dollies. The boxes were then rolled outside, loaded onto pallets, and subsequently hoisted into refrigerated tractor trailers for transport to a commercial cold storage facility in Laramie, Wyoming (approximately one hour north of Fort Collins). Empty bookshelves were being dismantled and piled around the perimeter of the basement. While conducting an initial assessment, I ran into one person who didn't seem to be employed by the disaster recovery firm, but inquired whether I had seen a copy of one of his favorite books. I believe he was looking for a volume of Kierkegaard! Large areas of this floor remained unlit, and numerous, water-logged volumes scattered randomly about the floor were being gradually ground into pulp under the boot heels of the untrained the temps.

The recovery was moving slowly and without sufficient care, but the situation came to a head the following morning at 7:00 AM during the daily orientation meeting when the University's consultant asked the library recovery firm to estimate its recovery costs for the library. The response was that the "packout" alone (e.g., removing the books from the library to a commercial freezing plant), would cost \$1.5 million; approximately \$3.50 per book. As this figure did not address cleaning or drying of the collection (which might have totaled \$20 million), the University's consultant called a meeting with President Yates and his Council to discuss the appropriateness of requesting a competitive bid .

The meeting with President Yates occurred later that afternoon lasted 25 minutes. After listening to the concerns of the consultant followed by my assessment of the situation, President Yates

terminated the contract with the first library recovery firm and replaced them with a second firm from Fort Worth, Texas that estimated the total recovery cost for the library (including packout, transportation, freezing, and drying) was \$2.3 million (\$5.45 per book). In the throes of a natural disaster which, by its very nature elicits knee-jerk reactions, this particular meeting evoked the most dynamic decision-making strategy I have ever witnessed. Unfortunately, lost in the process of contract termination was some critical information, such as the whereabouts of a missing semi-truck full of student records.

Bright and early on the fourth day after the draining of the basement, the second recovery company took control of the library's recovery operation. Small groups of temps (six to eight people) were assigned to individual supervisors who had complete authority to fire at will, immediately eliminating issues of temp accountability. The library's perimeter was secured and future access by well-meaning interlopers denied. Randomly strewn books were picked up from the floor; disassembled bookshelves were passed out of the building, via a human chain, and deposited in nearby construction dumpsters; and the carpeting was pulled up and removed to reduce the moisture content inside the building. Extension cords and task lighting were hung from the ceiling and darkened areas of the floor became illuminated. Paperboard boxes were assembled en masse in the basement, and lined with black plastic garbage bags to prevent the cardboard from becoming soggy. The boxes were filled with waterlogged books, marked on the sides with tracking and retrieval codes, and moved via two-wheeled dollies through the hole in the wall where the flood waters had originally entered the basement. An intermittent summer rain required a waterproof tarpaulin be placed over the conveyor belt that moved the boxes up to ground level where they were stacked 24-boxes-per-pallet in a 3 x 3 x 3 configuration. Each filled pallet was rotated on an industrial-sized Lazy-Susan and wrapped in clear plastic wrap to stabilize the boxes in transit. A propane-powered forklift was used to load the pallets into the refrigerated trailers of waiting semi-trucks. Each pallet was packed only one-high to avoid crushing the paperboard boxes, and a small aisle down the center of the tractor trailer was left clear.

At the suggestion of Dr. Robert McComb (Research Chemist, Library of Congress, now retired), a 20-ton tanker-trailer of liquid nitrogen was brought on site, and each of the fully loaded refrigerated tractor trailers ("reefers" in the parlance of the trucking industry) containing the wet collection was blast-cooled to radically reduce the temperature of the books. The liquid nitrogen was transferred to the reefers through a one-inch diameter plumbing pipe (with holes drilled about every 12 inches) slid under the back door of the trailer and down the small aisle between the pallets. To prevent liquid nitrogen from leaking through drain holes in the floor boards and freezing the truck's tires, plywood boards were placed between the rear tires and the bed of the reefer. This methodology proved effective for rapidly reducing the summer temperatures inside the reefers to allow the trailer's cooling system to operate more effectively on the short trip to the closest commercial cold storage facility in Laramie, Wyoming, and at \$500 per tanker-trailer, the cost proved quite reasonable: only two tanker-trailers were needed to complete the entire packout. The collection remained at this cold storage facility in Wyoming until the packout was completed, and was then transferred to a second cold storage facility in Fort Worth, Texas to be near the library recovery firm for further treatment.

A visit to the Wyoming facility about a week into the recovery revealed that the unlined, paperboard boxes removed by the first recovery firm during the first two days of the packout had become saturated and were now collapsing under their own weight, limiting to three high the height the now-crated pallets could be stacked. The boxes lined with black plastic retained their physical integrity, allowing each of these crated pallets to be stacked four high inside the commercial freezer and later facilitating further handling of the boxes without risk of doing harm to their contents. The “lost” reefer containing student records was discovered on a dirt siding near the freezer plant, its refrigeration unit shut off and the sweltering records reeking of deteriorating biological matter. The packout took a total of 14 days to complete.

Building Cleaning

Once the collection was removed from the Morgan Library basement, all damaged, detachable building components (carpet, wall board, ceiling tiles, etc.) were stripped from the space down to the concrete floor and the wall studs. Concrete surfaces and duct work contaminated by mold were disinfected with “Simple Green” and “Zep-O-Mint,” two commercially-available products each containing 5% o-Benzyl-p-chlorophenol. The duct work was then coated with “Foster’s,” an antibacterial agent containing barium metaborate, to prevent future regeneration of mold in those tight spaces.

Mold

Visible signs of mold appeared in the damp Morgan Library basement approximately three days after the water was pumped from the building. Efforts were initiated immediately to control the temperature and relative humidity within the basement which was isolated from the building’s first floor by taping black plastic sheeting over all doorways. Dehumidifiers, powered by portable diesel generators, were used to pump desiccated air throughout the building in an attempt to dry the basement and prevent mold from spontaneously spreading to the remaining four floors of the building. This tactic proved successful above ground, but little could be done to counteract the huge amount of moisture trapped within the wallboard, books, and other porous material in the basement. Portable air conditioning units were set up in the basement, but their cooling capacity was inadequate leaving temperatures to hover at approximately 65E F. (18E C.), not nearly cold enough to retard mold growth.

By the fourth day of the recovery, mold could be seen growing profusely on all flood-damaged surfaces, further damaging the already battered book collection and considerably complicating the recovery process. Mycologist Dr. Douglas A. Rice (Environmental Health and Safety, CSU) identified at least thirteen strains of mold growing in the basement,³ approximately half of which were feeding on the paper-based collection. Additionally, human safety concerns led to the use of particle masks to reduce the health risk to all workers during the day,⁴ and a desire to fumigate the library’s basement at night. Disagreement about which sterilant to apply delayed its use for two days. The debate hinged on the need to identify a sterilant that could be adequately dispelled from the closed space by morning to allow workers to safely breathe the ambient air and continue salvaging the collection. Finally, Ortho-phenylphenol (OPP) was settled upon and applications were sprayed on with bug sprayers during three successive nights after the work crew was released.⁵ This helped reduce, but by no means eliminate, the growth of mold in the Morgan Library basement.

The visible effects of mold on the collection increased with each day the books remained wet in the library basement. Active conidia became more and more noticeable on bookbindings and text edges, and, as time passed, staining became evident on the endpapers. This discoloration continued to progress into the leaves of the text until the books were finally frozen and the mold became dormant. Books recovered during the first few days of the packout exhibited little or no text staining, while books recovered in the last few days of the recovery frequently had damage extending 20 or more pages into the volume from either cover. Additionally, the first examples of dried books returned to CSU from freeze drying chambers in Texas (about 30 days into the recovery) contained a foul odor of decomposing organic matter not dissimilar to rotting sea life. It became abundantly clear that drying alone would not adequately address the mold problem.

In an attempt to respond to the growing concern about biological damage to the collection, conservators, chemists, and mold experts throughout North America were contacted to try to identify the most appropriate mass-sterilization technique for treating these books. During the course of this investigation I learned that the success with which conidia survive in nature is based on a number of variables, including the species' specific "resistance to deleterious agents, temperature extremes, chemicals, radiations, desiccation, competitive saprophytic ability, and mutational capacity."⁶ It also became clear that mold can be extremely hearty: in a test situation, cultures of *Aspergillus* were shown to survive for 22 years, while *Penicillium* survived for 10 years.⁷ Both of these molds commonly occur in library material and were present in the CSU disaster. It was also discovered that mold cultures can be preserved for long-term biological study by freeze drying⁸ or flash freezing with nitrogen, both of which occurred to the Morgan Library's books during the recovery process, and neither of which was responsible for killing more than a small percentage of the mold.⁹

Toxicological Issues

The degree to which people are affected by mold depends upon the species involved, level of exposure, and a person's sensitivity to it. The most common epidemiological reaction is allergic which, from person to person, varies in severity. A second mold reaction is intoxication which can occur as the result of ingesting or inhaling toxic mold metabolite. The third type of reaction is infection colonization of human tissue resulting in the growth of the organism within (or on) the body. People at the greatest risk of contracting mold infections are those with suppressed immune systems (e.g., people suffering from AIDS, undergoing chemotherapy, or recovering from an organ transplant), or weakened heart or lung conditions, including asthma.

Trying to define how much mold is acceptable on library books turned out to be a key to understanding the long-term public health risks faced by CSU in the aftermath of the flood. Dr. Harriet Burge (Associate Professor, Environmental Microbiology, Harvard School of Public Health), a preeminent expert on mold and human health issues in the U.S., suggested, "Visible, living mold is certainly not acceptable, nor [is it acceptable if] there is sufficient active mold growth so that moldy odors are evident," as mold odors can result from the presence of dormant spores. In terms of being able to quantify these observations, however, Dr. Burge explained, "There is no data on which to base surface measurements. I usually consider surfaces that are not visibly moldy and produce one or two colonies of mixed types per square inch [when incubated] to [be] normal. This is predicated on sampling considerably more than one square

inch surface, of course. On the other hand, if a surface produces an essentially pure culture of one fungus with more than twenty colonies from the test area sampled, then I would judge that active growth is still occurring.”¹⁰

Mold, whether living or dead, can cause human health problems. Dr. Burge continued, “The reason for sterilization is to prevent continued [mold] growth, not to reduce [human health] risk. Dead fungi contain allergens and toxins as well as live ones. The health effects from lung colonization can be ruled out as a result of sterilization, but hypersensitive reactions will not be eliminated.”¹¹ An equally significant concern is whether the sterilant used has the potential for causing toxicological problems of its own, and the duration of this secondary but equally important risk. This issue is at the heart of the current trend in U.S. conservation to avoid sterilization, a point summarized by John Haines and Stuart Kohler, who stated: “If a spore is an allergen when it is viable it is still an allergen when it is nonviable, but if it was treated with a toxin [e.g., a fumigant] it now has a coating of toxin in addition to its allergenicity.”¹²

And finally, a key question relating to CSU’s long-term liability was, “How long does dead mold on books remain a health risk?” Again, Dr. Burge explained, “Mold spores are designed to be resistant, so they last a long time. Allergens, however, are proteins and probably degrade with some rapidity, although no one has the slightest idea (as far as I know) what the time course might be for a dry spore. It is known that mold allergen extracts can lose potency within weeks.”¹³ To safeguard staff and patrons from ingesting mold as a result of handling infected library materials, a standard protocol for removing dry, inactive mold from a limited number of books is to vacuum the friable material into a high efficiency particle (HEPA) filter, sweeping it towards the vacuum cleaner nozzle with a soft brush (working in a well ventilated area or fume hood and wearing disposable gloves and a particulate respirator). The quantity of spores contained collectively in CSU’s 425,000 damaged volumes made this approach impossible, and an expeditious alternative was simply to wipe off the majority of visible, friable material after the mold was sterilized (workers wore protective clothing and used disposable rags).

Current Treatment Options for Mold

There are two diametrically opposed schools of thought governing the recovery of mold-damaged library material. The first advocates maintaining reduced RH levels inside the building to force mold spores into a non-active state and prevent further mold growth. The second champions the use of sterilants to kill mold spores. The reality is that both approaches have merits, but that once an outbreak occurs and people start expressing grave concern about human health risks, an optimal method for addressing mold on library material does not really exist yet. Further, precious little testing has been conducted to date to determine the long-term effects of sterilants on the permanence of library material.

Environmental Control

Maintaining stringent environmental controls (e.g., 68-72E F. [20-22E C.] and 40% RH +/- 5% with constant air movement¹⁴) within the storage facility will prevent mold from growing. Within this type of constantly controlled environment, nearly all types of germinating mold spores will also stop growing, and new spores will not germinate. However, many collecting institutions worldwide lack optimal (or any!) environmental controls, which can lead to circumstances that naturally promote mold growth. And, as in the case of CSU, even a facility

that normally operates an HVAC system capable of maintaining optimal temperature and humidity ranges can have that norm tragically interrupted.

Sterilization

As noted in a study by Haines and Kohler on fumigation of archival material, “To rid books and paper of mold problems by non-destructive chemical application with a minimum of human contact would appear to be an attractive course of action. The problem with this approach is that most fungicides are either hazardous gasses that pose a health risk to the user or solutions that may damage cellulosic material.”¹⁵ Given the fragility of book paper, a monumental obstacle to sterilizing books after a mold outbreak is the difficulty of killing every spore, including thoroughly penetrating the interior of the book’s pages. Even in an experimental setting where better than 99% of the conidia were killed by fumigation, Haines and Kohler acknowledge this to be “an almost insignificant loss to a fungus which can produce hundreds of thousands of spores in a small colony started from a single spore.”¹⁶ Further, as mold spores are ubiquitous in the Earth’s atmosphere,¹⁷ and that any sterilized surface provides an optimal medium on which new spores can germinate given the right conditions. Florian observed, “Parchments have been reported to be more prone to fungal infestation after ethylene oxide fumigation treatment.”¹⁸ Again, environmental controls remain a key to preventing ongoing outbreaks.

What follows is a brief review of some of the most common options.

Thymol

Thymol has been reported to provide effective sterilization of mold in books,¹⁹ but this treatment is known to deposit a very long-lived and unpleasant odor in paper that never seems to completely dissipate. Additionally, relatively recent testing draws into question thymol’s efficacy,²⁰ although this finding has been a topic of some debate.²¹

Ethylene oxide

Historically, ethylene oxide (EtO) was often recommended as the most effective sterilant for library materials,²² but even in a laboratory setting it has been shown to provide less than perfect results.²³ Dr. McComb noted that multiple applications of EtO improved its efficacy.²⁴

EtO has been registered as an antimicrobial pesticide since 1948 and is commonly used as a sterilant in health care facilities because of its potency to destroy pathogens through an alkalization reaction. It is also flammable and explosive, a known carcinogen, a toxic air contaminant,²⁵ and shown to off gas from books for a long (undetermined) period of time after treatment.²⁶ Protocols for using EtO in a commercial setting include: sealing and evacuating air from a chamber (typically large enough to drive in pallets of material), adjusting the temperature and pressure (e.g., slightly below atmospheric for pure EtO), soaking the contents of the chamber in the sterilant for 4 to 24 hours, evacuating the sterilant, and bathing the contents in a series of fresh air washes to remove residual EtO. Further aeration follows (three-to-five days) after the gas has been evacuated from the chamber to allow for the complete dissipation of the gas.²⁷ In the U.S., use of EtO is regulated by the Environmental Protection Agency. This material has fallen out use in North American library conservation,²⁸ and is avoided by commercial recovery companies due to concerns about future off gassing of EtO in confined spaces.²⁹

Ortho-phenylphenol

Ortho-phenylphenol (OPP) was successfully used by Dr. McComb in a library disaster recovery situation in 1976 at Temple University in Philadelphia, PA following the Klein Law Library fire, and remains his preferred sterilization option for library material.³⁰ OPP, a salt requiring application by hand as an aqueous spray, is a common, commercial sterilant frequently used as an antiseptic for hospital floors, on fresh fruit prior to shipping, and for many years as the active ingredient in Lysol[®] Brand Disinfectant Spray.³¹ Human safety issues are well understood with OPP which readily dissipates in air and which the Environmental Protection Agency classifies in a low-risk group of possible carcinogens (Group 2B).³² Opp's long-term effects on books and paper are less well understood. Robert Weinberg (Graphic Conservation Company, Chicago), expressed concern that over a period of 10 years he had observed OPP yellowing the paper backings on framed works of art.³³

Gaseous ammonia

Gaseous ammonia was recommended as a treatment option by Weinberg.³⁴ A material that holds some promise as it is inexpensive, gaseous ammonia poses few long-term toxicity problems, and may even improve the pH of paper as a bi-product of treatment. However, controlled studies have yet to be conducted to determine this material's efficacy as a sterilant or its long-term effects on paper.

Ozone

Ozone is commonly used in the disaster recovery industry to eliminate odors resulting from smoke. More recently, ozone has come under investigation by the Los Alamos National Laboratory for treatment of biological pathogens and seems to offer promising results,³⁵ but efficacy data related to a wide range of molds commonly associated with disaster situations is not available. On the CSU campus, Dr. Rice expressed interest in investigating its potential as a fumigant after ozone was successfully used to reduce the percentage of viable conidia in post-flood damaged buildings (other than the library). Ozone however, is one of the constituents of photochemical smog and well documented as a degrader of cellulose (e.g., cloth and paper) and dyes,³⁶ and as of this writing nothing is known about the long-term risks to books at the concentrations and duration of exposure necessary to kill mold.

Radiation

Both gamma and electron-beam radiation have been applied to commercial sterilization since the 1950s and bring to the problem the advantage of producing no harmful emissions. Gamma radiation is currently produced by cobalt-60, while electron-beam is ionizing radiation produced by accelerators ranging in energies from 3 MeV to 12 MeV (million electron volts); both kill mold by damaging the DNA molecule.³⁷

Only rudimentary research on gamma radiation as a sterilant for mold-damaged books had been done at the time of the CSU flood,³⁸ but subsequent investigations by Adamo et. al. (1998 and 2001) suggest that low-level radiation offers an effective option for sterilizing mold-contaminated, library material without causing significant damage to cellulose or posing long-term health risks.³⁹

Electron-beam (e-beam) radiation may also hold promise for treating mold-damaged books as the dose rate used is significantly less than with gamma radiation, but no testing has been done in this area to date.⁴⁰ In test situations, some healthcare products have proven to degrade less when exposed to electron-beam radiation than to gamma radiation, but the penetration is not as thorough. Observations from the commercial disaster recovery field suggest electron-beam radiation is not as effective as gamma radiation in practice due to the density of boxed books.⁴¹

CSU Treatment Specifications

A number of factors affected the treatment specifications designed for CSU's book collection. Being a research library, it was known that the damaged material was intended for long-term (permanent) retention. However, the collection was made up predominantly of scientific journals and monographs 100 years old or less, indicating that some material would be relatively easy to replace as opposed to treat.

While mold affected the collection to differing degrees, it is fair to characterize all of the books as having been thoroughly wet and affected by mold. Due to the number of items impacted (425,000 volumes), any technique adopted needed to be efficient and adaptable to a mass-production approach. And, the institution determined that sterilization was an important step for all material before returning the collection to active use to minimize the long-term health risks to its patrons from recurrent mold growth.

Replacement Program

Over a period of months, a list of all collection material damaged by the flood was extracted from the library's online catalog. This list was electronically distributed to research libraries throughout the U.S. with a plea that duplicate copies of the identified journals and monographs be sent to CSU as gifts to help Morgan Library expedite its recovery process. A generous response resulted and CSU received over 400,000 gift items. These books and journals were systematically sorted and compared with the shelf list, but despite the specificity of the items requested, only about one fourth of the gifts books received matched the flood-damaged items. As these 100,000 desirable items were identified, the material was accessioned and instructions sent to the library recovery firm in Texas to discard the damaged, duplicate copy.

Additionally, a photocopy page-replacement program was established through interlibrary loans. Pages badly stained by mold were excised from the text and replaced with photocopy replacements prior to rebinding, reducing the visual disfigurement caused in the most egregious examples of mold damage.

Washing and Drying

CSU's water-damaged books were shipped frozen using commercial overland trucking firms from the commercial cold storage facility in Wyoming to another commercial cold storage facility in Fort Worth, Texas. Books remained frozen until they could be treated by Belfor USA (2425 Blue Smoke Court South, Fort Worth, TX 76105, tel. 817-535-6793).

Before drying, the books were checked against the list of replacement gift items received by CSU and the damaged duplicates discarded. This searching to locate duplicates added

significantly to the total time on the job, one of several steps added to the protocol that contributed to the final cost being higher than the initial estimate.

The books were thawed, washing in clean, running water to remove dirt and mold, squeezed to remove excess water, and then re-frozen. Three freeze drying chambers were used simultaneously, with 7,000 frozen books treated per load (21,000 volumes total). The frozen books were wheeled into the chambers on mobile racks that were internally heated to approximately 95E F. (35E C.). Sublimation of the books occurred by maintaining the pressure inside each chamber below 4.57 mm Hg (typically, it was below 1 mm Hg), with the temperature ranging between 70E F. (21E C.) and 80E F. (27E C.) degrees Fahrenheit. The complete drying cycle, depending on the amount of water contained in the books, took between two and three weeks.

Sterilization

Following the drying process, the books were sent to SteriGenics , a commercial sterilization company (the Ft. Worth, TX office can be reached at 817-293-0999, with corporate offices at 8550 West Bryn Mawr Avenue, Suite 600, Chicago, IL 60631; tel. 800-472-4508) for gamma radiation treatment. Due to the variability of the density of each box of books, the radiation was guaranteed to range between 15 and 25 KiloGrays.

Wipe down and Shipping

Following sterilization, small amounts of mold not previously removed by washing were wiped from the book exteriors with natural rubber sponges, the volumes once again packed in boxes, placed on pallets, and shipped back to CSU by a commercial trucking firm.

Page Replacement and Rebinding

At CSU, the dried books were inspected and page replacements were ordered through interlibrary loan for badly mold-stained pages. Badly stained pages were removed, photocopy duplicates inserted in their place, and all other torn sheets repaired. The books were then sent for commercial library binding and the water-damaged covers replaced with new buckram bindings.

Total costs

The final cost for the treatment regimen performed by the library recovery firm (including packout; building cleaning; transport of wet books from Fort Collins, CO to Laramie, WY; freezing; transport of frozen books to Fort Worth, TX; washing; re-freezing; freeze drying; sterilization by gamma radiation; final wipe down; and transportation from Fort Worth, TX back to Fort Collins, CO) was approximately \$9.00 per volume (\$3,825,000).⁴² The total cost to the Library to return the entire water-damaged collection to active service, including the above mentioned treatment regimen, their own in-house processing, photocopying, mending, and commercial library rebinding was approximate \$30.00 per book (\$12,750,000). The process took approximately two years to accomplish.

Lessons Learned

1. **Buyer Beware:** Unfamiliarity with cost effective procedures and technical protocols, as well as severe disorientation and emotional shock that accompanies any disaster, puts the consumer at a terrible disadvantage when contracting for recovery services following an

event. Unscrupulous recovery professionals can (and do) take advantage of this naiveté and may charge inflated rates, offer to provide unnecessary services, or perform work poorly. (The time for negotiating the price of a life preserver is not when the ship is sinking!).

2. **Conservation Consultant:** A conservator experienced in disaster recovery should be identified as a key component of an institution's disaster plan and should be the first person hired following a disaster. Ideally, this person should report directly to the head of the institution to act as their advocate in negotiations with insurance adjusters and establish recovery protocols to guide the work of a commercial disaster recovery firm.
3. **Pre-Select the Commercial Disaster Recovery Firm:** Three days of organizational and recovery time were needlessly lost at CSU due to the initial selection of the wrong disaster recovery firm. This delay resulted in increased mold damage to the collection. Institutions are advised to pre-select a competent commercial disaster recovery firm in an informed way (scrutinizing prices, services offered, and previous customer satisfaction), and to pre-authorize this firm's services contractually to avoid delays or improprieties when awarding a recovery contract. The author would be pleased to discuss his experiences and offer recommendations on this point with anyone who is interested.
4. **Recovery Capital:** Money is critical to effectively implementing a disaster recovery in a timely fashion. Determining an institution's current insurance coverage, including limits of liability and exclusionary clauses in the policy is critical to creating a viable disaster response plan. Determining who within an institution is able to initiate this type of expenditure in a crisis should also be a part of the plan.
5. **Health and Safety:** Long-term health risks can arise from exposure to mold, infectious or hazardous agents, and unexpected workplace hazards (including electrocution). Disaster recovery can be physically exhausting, psychologically demanding work and should be conducted by people familiar with the attendant health and safety issues, and everyone involved in the recovery should take appropriate precautions.
6. **Controlling Mold:** Reducing mold growth in situ in a recovery situation requires immediate use of significant amounts of cooling, which can include in-house HVAC (when operational), portable air conditioning units, and refrigerator freezer trucks (including the use of liquid nitrogen). Temperatures within the flooded facility should be maintained at approximately 45E F. (7E C.) to effectively retard mold growth. Additionally, in a large-scale recovery, mold formation may be able to be delayed and retarded by inundating wet spaces with ozone each evening when the work crew is released, and "washing" the area with fresh air in the morning before work commences.
7. **Disaster Planning:** Each of the foregoing points are issues that can be addressed in an institution's disaster plan (which is only as strong as it is real). Post-disaster evaluation can also help prevent future problems; in the case of CSU, a retaining wall was constructed outside the Morgan Library designed to buffer the building from future flash floods.

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3. Fungal genera identified in the Morgan Library by mycologist Dr. Douglas A. Rice (Environmental Health and Safety, CSU) after the flood included: *Absidia*, *Alternaria*, *Aspergillus*, *Botrytis*, *Chrysonilia*, *Cladosporium*, *Curvularia*, *Fusarium*, *Paecilomyces*, *Penicillium*, *Stachybotrys*, *Trichothecium*, plus yeast.
4. Rossol, Monona, "Conservators and restorers face flood hazards," *Abbey Newsletter* 17, no. 3 (August 1993): 3-4. The article states: "A NIOSH-approved toxic dust mask is probably sufficient for moderate mold concentrations. For higher concentrations, use a cartridge respirator with toxic dust filters."
5. Technical specifications provided by Earlie Thomas, Director, Environmental Health and Safety, Colorado State University via email on 8 July 2003.
6. Mary-Lou E. Florian, "Conidial fungi (mould, mildew) biology: A basis for logical prevention, eradication and treatment for museum and archival collections," *Leather conservation news* 10 (1994): 1-28. See also, Mary-Lou E. Florian, *Heritage eaters: insects and fungi in heritage collections*, (London: James and James, 1997).
7. A. S. Sussman, "Dormancy and conidia germination in the fungi, an advanced treatise, " in G. C. Ainsworth and A. S. Sussman (eds.), *The fungal organism*, vol. 2, (San Diego, CA: Academic Press, 1966), 733-760. Cited in Florian, 1994.
8. John McCleary, *Vacuum freeze-drying, a method used to salvage water-damaged archival and library materials: A RAMP study with guidelines*, Paris: United Nations Educational, Scientific and Cultural Organization (UNESCO), 1987.
9. Dr. Douglas Rice, Environmental Microbiology and Industrial Hygiene Laboratory Director, Environmental Health and Safety, Colorado State University, personal communication, 7 October 1997.
10. Dr. Harriet A. Burge, Associate Professor of Environmental Microbiology, Harvard School of Public Health, Harvard University, LM-404M, 401 Park Drive, 4th Floor, Boston, MA 02215; email: hburge@hohp.harvard.edu, personal communication, 31 October 1997.

11. *Ibid.*

12. John H. Haines and Stuart A. Kohler, "An evaluation of ortho-phenyl phenol as a fungicidal fumigant for archives and libraries," *Journal of the American Institute for Conservation* 25, no.1 (1986): 49-55.

13. Burge, 1997, *op. cit.*

14. Experience indicates that air movement is a significant factor in mold prevention. When asked if she had observed the phenomenon that, all things being equal, mold seemed less likely to germinate in areas of a building with good air flow, Dr. Harriet Burge replied, "I have noticed the same thing. I assume it is because there is more chance of condensation and less of evaporation in such sites. I think air circulation is an important preventive measure, especially in spaces where there are lots of nooks and crannies." Personal email communication, 23 July 2003.

15. *Ibid.*

16. *Ibid.*

17. Harriet A. Burge et al., "Fungi in libraries: an aerometric survey," *Mycopathologia* 64, no. 2 (1980), 67-72.

18. Mary-Lou E. Florian, 1994: 8.

19. Mary-Lou E. Florian, "The thymol cabinet–fungicidal efficiency," (Research report), Canadian Conservation Institute, 1975, cited in Haines and Kohler, 1986.

20. Haines and Kohler, 1986, *op. cit.*

21. Mary-Lou E. Florian, "Letter to the editor," *Journal of the American Institute for Conservation* 25, no. 2 (1986): 109.

22. Burge, 1997, *op. cit.*; Dr. Michael Rinaldi, Department of Pathology, Veterans Administration Hospital and University of Texas Health sciences Center, San Antonio, TX, personal communication, 10 November 1997.

23. Haines and Kohler, 1986, *op. cit.*

24. Dr. Robert McComb, Research Chemist, Library of Congress, Washington, D.C., personal communication, 23 October 1997.

25. General information about EtO can be found at U.S. Department of Labor Occupational Safety & Health Administration (OSHA), *Safety and health topics: ethylene oxide* (7 January 2003), at: <http://www.osha-slc.gov/SLTC/ethyleneoxide/> Information about EtO's toxicity to humans can be found in, U.S. Department of Health and Human Services Public Health Service National Toxicology Program, *Ethylene oxide - the tenth report on carcinogens.*(December

2002), <http://ehp.niehs.nih.gov/roc/toc10.html>. See also, Sterigenics (2015 Spring Road, Suite 650, Oak Brook, Illinois 60523; Tel: 630-928-1700 / 800-472-4508; E-mail: info@Sterigenics.com), "Sterilization alternatives: ethylene oxide," at: <http://www.sterigenics.com/qeo.asp>

26 Frank H. Hengemihle, Norman Weberg, and Chandru J. Shahani, "Desorption of residual ethylene oxide from fumigated library materials," Preservation research and testing series no. 9502 (Nov. 1995), at <http://www.loc.gov/preserv/rt/fumigate/fume.html>

27. U. S. Environmental Protection Agency, *Pesticides: Topical & Chemical Facts Sheets, Ethylene Oxide* (19 May 2003) at: <http://www.epa.gov/pesticides/factsheets/chemicals/etofactsheet.htm#bkmrk6>

28. Richard Strassburg, "Further information on the use of ethylene oxide as a library and archival fumigant," Society of American Archivists leaflet (1983), cited in Haines and Kohler, 1986. See also, Mary W. Ballard and Norbert S. Baer, "Ethylene oxide fumigation: Results and risk assessment," *Restaurator* 7 (1986): 143-168; Robert McComb, "Three gaseous fumigants," *WAAC Newsletter* 2(3) (September 1980); Mary-Lou Florian, "The effect on artifact materials of the fumigant ethylene oxide and freezing used in insect control," *ICOM Preprints* (1987): 199-208; John E. Dawson, "Ethylene oxide fumigation: A new warning," Canadian Conservation Institute (nd); David Hillman, "Fumigation at the B.C. Provincial Museum," *IIC-CG Newsletter* (1982 or 1983?). I would like to thank Jane Hutchins for providing me with these last five citations.

29. Dr. Ruperet Pentenrieder, Senior Vice President for Technical Support, Belfor International GmbH, Oskar-Messter-Str. 885737 Ismaning / Germany, email communication 24 July 2003. "We really do have some fears using EtO for disinfection of materials that are to be used afterwards in closed areas and under uncertain conditions."

30. Dr. Robert McComb, "The treatment of mold, mildew, fungi, or microflora on library, archives, museum, and other depository materials: Fogging procedures," typescript, Library of Congress, Washington, D.C., 1992.

31. Dr. Robert McComb, Research Chemist, Library of Congress, Washington, D.C., personal communication, 1 September, 3 September, 10 September, 23 October, 4 November, and 19 December 1997. Currently, the active ingredients in Lysol Brand II Disinfectant Spray are Alkyl (50% C14, 40% C12, 10% C16) Dimethyl Benzyl Ammonium Saccharinate 0.1%, and Ethanol; the inert ingredients are water, fragrance, and propellant. (Information based on correspondence dated 2 July 2003 from Donna Davis, Consumer Relations Coordinator, Reckitt Benckiser North America, P.O. Box 945, Wayne, NJ 07474-0945).

32. Esther Rinde. Science Analysis Branch, U. S. Environmental Protection Agency, "Carcinogenicity peer review of orthophenylphenol (OPP) and sodium orthophenylphenol (SOPP)," memorandum, (August 24, 1994).

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40. Sterigenics (2015 Spring Road, Suite 650, Oak Brook, Illinois 60523; Tel: 630-928-1700 / 800-472-4508; E-mail: info@Sterigenics.com) "Sterilization Alternatives: Electron Beam Radiation," at: <http://www.sterigenics.com/qe-beam.asp>

41. Personal communication with Kirk Lively (Director of Technical Services, Belfor USA, 2425 Blue Smoke Court South, Fort Worth, TX 76105, tel. 817-535-6793) on 25 July 2003.

42. Technical specifications for treatments conducted for CSU's Morgan Library, as well as all fiscal estimates for the work accomplished, were provided by Kirk Lively via email on 7 July 2003.