

# The use of gamma rays in book conservation

BY PATRICK SINCO

UNLIKE ITS ROLES in medical sterilization or food disinfection, gamma irradiation remains far from the front-line of treatments in the field of book conservation. Although it can be used for the same purpose—to kill mold and other fungi, as well as bacteria, in damaged documents—the practice of exposing valued papers to ionizing radiation is recommended only in certain, desperate circumstances. That said, irradiation is a young, promising, and relatively untested treatment in the preservation field—and as such is both scorned and lauded.

Intermittent studies performed over the past three decades have identified the damage that irradiation can impart to paper—or, more specifically, to cellulose, the chief component of paper. Although paper can be produced using anything from animal furs to metal, most paper is produced from cellulosic plant fibers, and principally those obtained from wood pulp, cotton, and linen. During irradiation, free radicals can be unleashed in the cellulose and quickly react with oxygen to break cellulose molecules and degrade the paper.

Irradiation's propensity for aging paper prematurely is borne out in a number of studies. A 1994 European study, led by Judith Hofenk de Graaff, compared the effects of gamma radiation and ethylene oxide (once a standard for treating mold-infested materials) on the aging of paper. The chemical and physical properties—such as folding endurance, internal tearing resistance, stiffness, and pH level—were measured on five different kinds of papers following treatment, both before and after the paper was artificially aged. A 10 kilogray (1 megarad) dose accelerated the aging process in the irradiated papers by 50 to 100 percent, depending on the paper, according to the study, while the EtO treatment did not affect the aging of the paper. A 1998 study that appeared in the German journal *Restaurator* described the effects of increased doses of gamma rays on cellulose paper, both before and after mechanical aging. The radiation treatment decreased polymerization in the paper and caused it to turn yellow. A pair of studies that appeared in the March and June 1999 issues of the *Taiwan Journal of Forest Science* revealed a decrease of up to 15 percent in the mechanical properties of the papers tested at low to medium levels of irradiation, while at high doses the papers showed significant decreases in brightness and increases in yellowness.

So much for irradiation in book conservation?

In a field that strives to preserve materials, a treatment that may incidentally degrade materials can also greatly contribute. A slightly yellowed or embrittled document can be tolerated when the alternative is no document at all.

“Radiation has a place, if only because all the alternatives have their drawbacks,” said

*The book conservation world has been wary of treating infested books and documents with radiation, but sometimes nothing works better.*



**Pulled from the wreckage:** When the floodwater was finally pumped out of the basement of the main library at Colorado State University, library officials were faced with restoring damaged books such as these. (Photos: Colorado State University)

Ellen McCrady, who edits *The Abbey Newsletter*, which has been tracking the field of library and archival materials preservation for 25 years. “[Conservationists] know the irradiation degrades paper and parchment, but . . . the mold and insects will also continue to degrade the materials if they are not killed.”

“I think [irradiation] needs some open minds,” said Dennis Allsopp, a retired microbiologist and current U.K.-based consultant who specializes in work for libraries, museums, and archives. “There has been work done by the conservation world where, because someone said, ‘Well, we think that this actually causes a little bit of damage,’ people have written it off and said, ‘Oh, we can’t have anything that causes damage.’”

“Well, of course, any treatment—handling a book, fumigating it—will probably cause some sort of damage. If you want to be a total purist, you can just sit and watch the thing rot and weep over it.”

## The Gantt papers

The pilot project in the United States on the use of irradiation to disinfect archival materials began in 1980 when the medical archives of Johns Hopkins University inherited a collection of documents from a public health officer named W. Horsley Gantt. The materials, however, had been stored in a dilapidated row house in Baltimore that was infested with insects, rodents, and dog and cat carcasses.

When a team of archivists first showed up at the house, “things were strewn about—it was in total disorder,” Nancy McCall, an archivist at the JHU Alan M. Chesney Medical Archives in Baltimore who led the effort to preserve the Gantt collection, recalled recently. But what they found littered among the rubbish (which also included stray car fenders and giant balls of string) made clear that they would need to discover a way to preserve the collection.

Dr. Gantt lived Petrograd, Russia, in the years following the Revolution in 1917. He had collected valuable public health documentation, such as letters, photographs, and diaries, as well as rare public health posters from pre-Revolution Petrograd—all of which were found in the row house. Gantt’s correspondence with psychologist B. F. Skinner and author John Dos Passos were also found. Most notably, Gantt’s papers and letters from Russian physiologist Ivan Pavlov were stored in the row house; Gantt was the only American to study with Pavlov.

“Since it was a very valuable collection, we felt it was important to make a very concerted effort to save the material, to clean it up,” McCall explained. (McCall was familiar with valuable collections, having served as a volunteer during the devastating flood of the Arno River in Florence in November 1966. The *angeli del fango*—or “mud angels,” as they were called—were students and conser-

vators from around the world who came to rescue invaluable centuries-old paintings and manuscripts from the flood waters.)

McCall and her colleagues at JHU began to contact large archival programs, like state archives, that had larger treatment facilities. "We were very up front about what the problems were, and that just scared people. They didn't even want their loading docks contaminated," McCall said.

McCall had heard of using ionizing radiation for disinfestation, but didn't know much about it. After a search through the literature, she found mention of its use in eastern Europe to treat artifacts—and little else. "A lot of conservators with whom I spoke thought it was high risk. But we felt that we had no alternative but to take that risk." She then contacted Walter Chappas, who was a nuclear engineer at the University of Maryland at the time (and is now vice president and technical director for Damilic Corporation, in Rockville, Md.), to do preliminary test samples. Chappas performed tests using a linear accelerator to establish dosage level and exposure time so that the extermination process would be effective and minimize damage to paper and ink composition.

"When you're asked to take thousands of books that may have been published over 100 years, with different materials, different adhesives, different printing inks," Chappas said, "the legitimate engineer has to ask himself, 'We may kill all the bacteria, but are we also going to damage these materials in the process?'"

After working out a plan with a commercial radiation facility, McCall and her fellow archivists lined page boxes with plastic garbage bags, packed in the papers, and sealed the boxes. In all, 295 record storage boxes of Gantt's papers were exposed to 4.5 kGy (0.45 Mrad) of gamma radiation from a cobalt-60 source for approximately 45 minutes. Afterward, 10 cultures produced from a broad sampling of the irradiated materials revealed only one minor and incidental strain of mold, which was most likely introduced when the materials were unpacked.

"We had absolutely no problems—nothing," McCall said, and mentioned that there have been no problems with the documents in the nearly 20 years since the materials were placed in the Chesney Archives. "We were severely criticized at the time by very conservative conservators," McCall said. "But, truly, there has not been one conservation problem."

"We never want to suggest that this is the magic wand," Chappas explained, "and that you can take these heavily infested manuscripts and other documents, send it through the irradiation vault, and out the other side comes this pristine document that's clean and stable. The fact is there's potential for problems."

"But, the good news here was that we took samples that would otherwise have been lost. We did this technique and it not only solved the immediate problem—killing all the bacteria [and other contaminants]—but, in fact, did it in a way where the long-term damage has been apparently immeasurable at this point."



**Flood ruin:** The scene in the library basement was bleak soon after the nearly 5 million gallons of water were pumped out. The 1997 flood damaged 462 500 books, journals, and periodicals.

### Misconceptions

The reputation of irradiation certainly suffers the same problems among book conservators as it does most everywhere else. Namely, people fear all things "radiation." Some people in the conservation field quickly dismissed the technology when asked about its role in the preservation of books, as if it were useless to discuss.

"There is the psychological point that everybody gets so scared if they hear the word 'radiation,'" said Bert Van Zelst, director of the Smithsonian Institution's Center for Materials Research and Education. "That's the usual thing everywhere. But it is effective. There's no doubt that it's effective."

If only for control of insect pests in books, using much lower doses—0.5 kGy (0.05 Mrad)—than required for mold disinfestation, irradiation does have an unassailable role to play in book conservation. Looking at a higher dose level, a 1992 study published in the German journal *Restauro* described the minimal optical and mechanical effects on mold-infested historic books at the Leipzig Univer-

sity Library when given 12 kGy of gamma radiation, and noted that "severely attacked historical books showed improved quality after having undergone the described treatment."

"One of the problems is the scientific world and the art world—the conservation world—have often found difficulty in getting together," Allsopp said, "for reasons that people in them come from very different disciplines and are trained in different ways and mix socially in different ways."

Others expressed concerns about gamma radiation that appear to result from hearsay rather than fact. A few mentioned the difficulty, if not implausibility, of convincing a food or medical irradiation facility to accept their dirty books. Ruth Garcia, a plant operations manager for Isomedix, which operates 15 irradiation facilities in the United States and Canada, said they readily accept infested books, provided a number of measures are taken to package the material to isolate the contamination.

Still others—even those in advanced positions at elite institutions—have more trou-

bling misconceptions. The comments of a senior scientist at one of the world's leading conservation institutes—who admitted irradiation was not his specialty but goodnaturedly responded to a few questions—are telling. In enumerating some of the disadvantages of gamma irradiation, he noted “You have to have a reactor,” which certainly would present an obstacle if it were true.

He also said that irradiation is not needed in book conservation: “You just keep the books dry and you have no problem.”

### Disaster recovery

The only thing unusual about the late Sunday afternoon storm a few years ago that burst over the college town of Fort Collins, Colo., located about an hour's drive north of Denver, was the storm itself. The summer had been unusually arid, with rainfalls totaling less than half an inch for the region since the middle of June. Even as low, dark clouds lingered in the foothills of the Rocky Mountains after the storm ended—instead of clearing after dark in accord with normal summer weather patterns—there was little indication that the evening storm would be but a prelude to the most intense rainfall the region had ever seen.

The clouds released a steady torrent of rain through the night, and area residents awoke to a cool, gloomy Monday morning. By midday, curiosity turned to concern as continued rains led to accumulations of between 2 and 10 in. in locations in and near Fort Collins since the previous afternoon. The creeks and ditches were running full.

As flooding began to be reported in a nearby town, the rains had abated across the region in the afternoon. The air, however, remained unusually humid. Showers again erupted, and by 8:30 p.m., after two hours of heavy rains, the rains diminished in the east and southeast areas of Fort Collins.

The next hour-and-a-half, however, brought accumulations of rain over western portions of the city the likes of which had never before been recorded. Since hourly data were first published in 1940, the campus of Colorado State University had never experienced as much rain in a similar period as the 5.3 in. that fell between 6 p.m. and 10:30 p.m. on that Monday, July 28, 1997. Flood waters roiled through campus, and by morning there would be 10 ft of water in the basement of the main library.

“It's bad. It's a real mess,” Camila Alire, CSU dean of libraries, was quoted at the time in *The Coloradoan*. “But the books are salvageable.”

Mold can begin to form on a wet book within hours. Once it has bloomed on an item, it will reappear whenever favorable environmental conditions, such as high temperatures and high humidity, allow. As such, mold can never be eradicated unless it is killed.

Chemical treatments to kill molds in library collections are currently discouraged because of their toxicity. Indeed, exposure limits of ethylene oxide have been regulated to the extent that EtO—once a mainstay for mold control—is no longer a viable treatment option,

according to Mark Gilberg, a research coordinator at the National Center for Preservation Technology and Training. “For me, many years it was ethylene oxide,” Gilberg said. “But the exposure limits got to the point where they were so low that it was almost impossible to carry out.”

“Ethylene oxide is the main alternative to radiation,” Ellen McCrady stated, “but we know now that it is very hard to get back out of certain materials . . . no matter how many times the air is purged while they are in the chamber. . . . The EtO that remains will eventually escape from the book or document and endanger staff and readers.”

Other accepted treatments, such as freezing or placing the materials in a low-oxygen environment, can be effective in limiting the growth of molds. They do not kill the mold, but send them into a dormant state. A cool, dry environment with plenty of air circulation must still be maintained in the room where the collection is stored to prevent an outbreak recurrence.

“Mold can be a very big problem depending on where you are in the United States,” Gilberg said. “It's a big problem here, down south. . . . Mold develops. And you have to react quickly.”

Within days of the Colorado University flood, work crews began the task of removing nearly 500 000 books, periodicals, and journals from the library. Two weeks later nearly all the books were wrapped individually and placed into approximately 60 000 boxes. They were then shipped on a refrigerated truck to a freezer storage facility in Wyoming.

Meanwhile, the library was sending samples of damaged books across campus to a microbiologist, who then tested different treatments. “We were trying to find the easiest, safest, and fastest way to clean and sterilize the books,” said Doug Rice, director of CSU's Environmental Quality Laboratory, who performed the studies. “We tried several chemical methods, wet methods, cleaning methods. We tried ozonation. And we tried cobalt-60 gamma irradiation.”

“We consulted with the Library of Congress,” remembers Carmel Bush, the library's assistant dean for technical services. “We talked to people about what was best to do. We also had independent physical chemistry consultants. We had a number of points of view.”

According to results published in a forthcoming book about the library's recovery effort, gamma radiation achieved a 100 percent reduction in mold and yeast in Rice's book samples. The next closest reduction was 56.4 percent.

“We thought our experience and testing showed [irradiation] would work,” Bush said. “And, because we were controlling it in the low-dosage levels, we did not expect any of the problems that could be reported in higher doses. . . . That led us to feel that it was a good treatment choice.”

A query about irradiation posted on an Internet mailing list by a worker from one of the library's recovery subcontractors was answered by a SteriGenics International employee, and a plan to irradiate nearly half-a-

million books at the company's Co-60 facility in Fort Worth, Tex., was begun.

The books were taken out of cold storage and thawed. The covers were removed and the pages were washed and shaped into a block. The books were then freeze-dried before being shipped to the irradiation facility in Fort Worth, where they were given an average dose of around 15 kGy (1.5 Mrad). After irradiation, the books were further cleaned and inspected by another recovery subcontractor in Fort Collins. They were sent for rebinding, and then carefully again inspected and repatriated into the library's collection.

The process, however, is far from finished. Bill Parkin, of Belfor USA (formerly Disaster Recovery Service)—CSU's Fort Worth-based subcontractor—estimates that 100 000 volumes yet remain.

“We're still in the process, so we haven't engaged in any longitudinal testing,” Bush said when asked about the irradiation's noticeable effect on any books. “But we really don't expect that there's going to be any long-term effects. Our belief is, they are as they are, and we don't see anything relating to the radiation. I think if we had used high-dosage irradiation, we'd be talking about a different story, but we're not. . . .

“Mainly what [effects on the paper] we see is damage from being underwater. The paper suffers from wrinkling, it suffers from discoloration . . . You will see the stains where the mold was. But, obviously, we have no active mold in it—it's completely dead. We're real pleased about that.”

### Coming of age?

For now, gamma irradiation in the preservation of books and archival materials has been most successful in emergency circumstances. Although the two examples provided are the only two well-known instances in the United States in which irradiation was used to disinfect books on a large scale, Mark Smith, director of technical services for SteriGenics International, indicated that his company has done similar work on collections of flood-damaged books. He also mentioned that it is preparing to irradiate some damaged internal documents of a major petroleum refiner.

“The trouble is, with a lot of this sort of commercial work, people don't shout it from the rooftops,” said Dennis Allsopp, who was once president of the International Biodeterioration Society. “This is one of the problems with biological attack on materials—it's like people don't normally publicize their illnesses. People don't often make a big point that they've had a problem in their factory. They have it cured and solved, if they can, and they're just happy that they've solved the problem.”

Allsopp mentioned that it was during the Florence flood when a largely experimental technique—now widely used—was attempted out of necessity. “At the time . . . keeping things cold and freezing was thought to be terribly adventurous, but it had to be done because they just had tons of material which would have gone rotten otherwise. And it worked.”

Sinco P (2000) The use of gamma rays in book conservation. Nucl News, pp 38-40Google Scholar. 54. Smith PA, Sheely MV, Hakspiel SJ, Miller S (2003) Volatile organic compounds produced during irradiation of Mai. AIHA J 64(2):89-195CrossRefGoogle Scholar. 55. Sequeira S, Cabrita EJ, Macedo MF (2012) Antifungals on paper conservation: an overview. Urban J, Justa P (1986) Conservation by gamma radiation: the Museum of Central Bohemia in Roztoky. Mus Int 151:165-167Google Scholar. 62. UNE 57092-4 (2002) Papel y Cartón. Envejecimiento acelerado.Pte.4:Tratamiento con calor hmedoa 80 °C y 65% de HR. Asociación Española de Normalización y Certificación(AENOR), p 8Google Scholar. 63. We covered the interaction of gamma-rays with matter from a descriptive viewpoint in the previous chapter and we saw that the Compton and Photoelectric Effects were the major mechanisms. We will consider the subject again here but this time from an analytical perspective. This will allow us to develop a more general understanding of the phenomenon. Note that the treatment here also refers to the attenuation of X-rays since, as we noted before gamma-rays and X-rays are essentially the same physical