

Chapter 6

Health and Environmental Effects



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INTRODUCTION

As with any new process, there is a need to consider the human health and environmental impacts of DEZ treatment of large quantities of books and papers. The Library of Congress has begun a number of studies and intends to do further work prior to building a full-scale treatment plant. This chapter summarizes information about zinc, the health effects of zinc and zinc oxide, the Library risk assessment, and environmental impacts. Concerns about the need for the Library's risk assessment are presented in the Discussion section.

The compounds used and produced during the DEZ process are DEZ, water, ethane, and zinc oxide. Although there is currently little evidence to indicate that any of these compounds produce serious health effects, the Library is evaluating the risks the process may pose to workers, librarians, and library users. The Library's effort focuses on zinc oxide, which will be present as particles in the treated books and as dust in the work environment. Of particular concern is the inhalation of these zinc oxide particles. The Library also plans to determine whether any intermediate compounds are formed during the process that would warrant toxicological investigation.

The biological contribution and health effects of zinc and zinc compounds have been studied for many years. Most of the literature relating to inhalation have focused on the effect acute or sub-chronic exposures have on respiratory function and illness. There have been no tests studying the carcinogenic, teratogenic (birth defects), or reproductive effects of chronic zinc oxide inhalation. Therefore, the Library, with the help of two consulting toxicologists, has designed an animal study to investigate these effects after chronic exposures to the zinc oxide produced by the DEZ process. The results of these animal studies will be combined with exposure measurements at the plant site and at the Library to provide a complete risk assessment.

The other compounds associated with the process are not expected to pose any serious health problems. Ethane is considered to be a relatively benign compound. It is not considered carcinogenic or mutagenic. It is, however, governed by the OSHA limits on hydrocarbons, and can cause asphyxiation in closed quarters.

DEZ is not considered to be a toxicological hazard, either. Its pyrophoric nature precludes exposure. However, dilute liquid mixtures of DEZ can remain stable in air and cause severe burns if it comes in contact with the eyes or skin. (See *Risk to Workers* in previous chapter.) The Library, in an effort to test the toxicity of dilute gaseous mixtures of DEZ, exposed rats to hexane gas containing 20 percent DEZ by weight. The tests were inconclusive. Hexane itself is toxic, and rats exposed just to hexane demonstrated similar behavior as those exposed to the hexane-DEZ mixture. Autopsies showed no indication of growths or irritation in either case. Unless there is any indication that exposure to dilute concentrations of DEZ is a possibility, DEZ should not be a toxicological problem.

There have been two recent reviews of the literature on zinc and zinc oxide. The EPA Office of Health and Environmental Assessment reviewed the literature in 1987 in an effort to assist the Office of Air Quality Planning determine whether these substances needed to be regulated as hazardous air pollutants.¹ They concluded that no regulations were needed. The literature was also reviewed by Leonard et al. in 1986.² These two reviews provided most of the following information.

¹Office of Health and Environmental Assessment, U. S. Environmental Protection Agency, *Summary Review of Health Effects Associated with Zinc and Zinc Oxide: Health Issue Assessment*; August 1987.

²Leonard, G. B. Gerber, and F. Leonard, "Mutagenicity, Carcinogenicity and Teratogenicity of Zinc," *Mutation Research* 168: 343-353, 1986.

ZINC

Zinc is an important trace element in all living organisms and in all tissues. It is found in the blood, kidney, pancreas, liver, prostate, skin, bone, and eye. More than 20 zinc-containing proteins have been identified. These proteins have both structural and functional roles. Zinc enzymes assist in the synthesis of nucleic acids. Zinc also intervenes in a number of physiological functions as well, including various immune responses, the metabolism of hormones, and the stabilization of DNA's double helix. Zinc can also displace other metals. In the case of cadmium, mercury, and lead, the displacement is beneficial. In the case of iron and copper, the displacement has adverse effects.

Zinc is naturally found in small concentrations in the environment (see table 14). There are many manmade sources of zinc. These include metal mining, smelting, the production of zinc oxide and the manufacture of products containing zinc oxide, and

Table 14.—Zinc Concentrations in the Environment

Soil	10 to 300 $\mu\text{g/kg}$
Fresh water (unpolluted)	Less than 10 $\mu\text{g/L}$
Surface water (polluted)	As high as 21 mg/L
Air (around zinc smelters)	Less than 1 $\mu\text{g/m}^3$ to 15 $\mu\text{g/m}^3$
Air (around certain work sites)	As high as 18 $\mu\text{g/m}^3$

SOURCE: Environmental Protection Agency, 1987.

the burning of refuse. Zinc is used for galvanizing steel and in the production of rubber; and zinc oxide is used in pigments and in skin ointments, astringents, and antiseptics. Zinc oxide is also used to coat Xerox papers and thus is present in many office environments.

The zinc content of the average daily diet ranges from 8 to 18 mg/kg . Most of this is from food and drink. Intake through the skin or inhalation is minimal. The daily recommended allowance for adults is 15 mg/day .

HEALTH EFFECTS OF ZINC AND ZINC OXIDE

Toxicity

There are no adverse effects associated with dermal exposures to zinc or zinc oxide. In fact, there are many zinc compounds used for medicinal purposes, including zinc ointments for the healing of wounds. Zinc compounds are found in baby powders. The Library conducted earlier toxicology tests on rabbits, exposing them to papers treated by the DEZ process. The results indicated that there was no dermal toxicity.

Excessive or chronic oral ingestion of zinc can cause some health effects. Long-term feeding of zinc salts to rodents retarded growth, and led to anemia and metabolic effects. Excessive ingestion can lead to anemia due to the displacement of iron. There was some incidence of anemia attributed to zinc ingestion in children who played with zinc cast toys in alkaline bath waters. The effect can be reversed with the consumption of iron. Ingestion of zinc in excess of 400 ppm is known to cause gastrointestinal distress, including nausea and diarrhea. There have been recorded many incidence of people experiencing these effects after consum-

ing food or drink from galvanized containers. Long-term ingestion of excessive amount of zinc or zinc oxide can cause immunological and cardiovascular effects. However, there is no evidence that chronic ingestion of zinc is poisonous.

The acute inhalation of zinc or zinc oxide particles, on the order of 0.15 μm in size, can produce adverse health effects known as "metal fume fever". It is normally associated with welding and other zinc industrial environments. The symptoms include fever, nausea, headaches, and dryness of the mouth and throat. The effects are reversible in 24 to 48 hours. OSHA has set an acceptable exposure level at 5 mg/m^3 for an 8-hour workday. Subchronic exposure to zinc oxide fumes, even somewhat below the OSHA level may cause gastrointestinal damage such as peptic ulcers and liver dysfunction and increased respiratory illness and infection. Whether these effects can be expected from working around the treated books or during plant operation, depends on the particle size and the amount of exposure. This will be discussed in the section on exposure.

Mutagenicity, Carcinogenicity, Teratogenicity

Zinc is not considered mutagenic. There is some evidence that zinc acetate may cause chromosomal aberrations in certain cells, but the cells that were studied were not those normally used for studying chromosomal damage.

There is no clinical evidence that indicates ingesting or inhaling zinc or zinc oxide causes tumors. Examination of a variety of tumors show no correlation with zinc concentrations in the tissue. However, there have been no valid studies from which to evaluate zinc's carcinogenicity. Tumors have been caused by repeatedly injecting the testicles of birds and rodents with zinc salts. Zinc metal powder injected into the trachea of animals has also produced tumors. In all of these cases, the tumors were located at the site of injection. Injection is not considered a valid exposure route and unless it causes tumors away from the site of injection, it

is not considered a valid indication a substance's carcinogenicity.

Because of zinc's role in DNA synthesis and cell growth, zinc has been associated with promoting the growth of certain tumors. In other cases, zinc has inhibited tumor growth.

Zinc is not considered to be teratogenic. In fact, zinc deficiency is known to be a major cause of birth defects, and zinc can reverse the teratogenic effects of cadmium. For this reason zinc supplements have been given to pregnant women. However, there have not been any teratogenic studies related to the chronic inhalation of zinc oxide.

Excessive zinc has adversely affected fertility and pregnancy in rats. The effect may or may not be similar in humans. Normal levels of zinc do not appear to be a problem. Pregnant women who have been given zinc supplements, up to 81 mg/day during their final 3 months of pregnancy, have shown no adverse effects.

LIBRARY'S RISK ASSESSMENT

Animal Study

The Library has designed an extensive animal test to study what effects the acute (14 days), sub-chronic (91 days), and chronic (2 years) inhalation of zinc oxide particles may have on pulmonary function and male and female reproductive capabilities, and to determine the carcinogenicity and teratogenicity of chronic inhalation of zinc oxide particles. The study will expose rats to acute, sub-chronic, and chronic inhalation of zinc oxide particles at various concentrations in air, including a zero percent zinc oxide control. Clinical and gross pathologies will be performed on all specimens and organs. Pulmonary physiology will be examined in some specimens and pathology of the respiratory track will be performed on all specimens. An examination of sperm morphology and vaginal cytology will also be performed on specimens in the sub-chronic and chronic studies. Some specimens from the sub-chronic exposures will be mated to study the reproductive and teratogenic effects.

All tests will be performed in accordance with the National Toxicological Program guidelines for good laboratory practice.

Exposure Study

As part of its risk assessment, the Library is determining the particle size and levels of exposure that can be expected for library users, librarians, and process workers. Particle size will determine how deep the particles may go into the lung (e. g., respirability). Particle size v. respirability is given in table 15.

Library users can be expected to be exposed to zinc oxide by leafing through a book. Two methods were used to determine the amount of zinc oxide to which a user may be exposed. One method was to vacuum loose zinc oxide off randomly selected pages of treated books. The other method mechanically leafed through books and sampled the air 5 inches above the pages.

Table 15.—Particle Size v. Respirability

Particle size (μm)	10	5	3.5	2.5	2
Percent respirable	0	25	50	75	100

SOURCE: Northrup Services Inc., "Evaluation of Diethylzinc-Treated Paper: Particulate Emissions," Final Report to the Library of Congress, August 1985.

Librarian exposure will be determined by measuring the ambient air concentration of zinc oxide in a simulated stack of treated books.

Worker exposure will be determined by taking air samples at the chamber door, when the door is opened and closed.

Results from the user exposure study indicated that the particle or aggregated particle size averaged 0.6 to 1.5 μm by 0.4 to 1.0 μm . Particles of this size are respirable, but 90 percent of those measured were above the 0.15 μm particle size related to metal fume fever.³ In addition, the maximum airborne concentration, 5 inches above a me-

³Northrup Environmental Sciences, Triangle Park, NC, *Evaluation of Diethyl Zinc-Treated Paper: Particulate Emissions*, a report prepared for the Library of Congress, August 1985, p. 4-1.

chanically leafed book, was 0.06 $\mu\text{g}/\text{m}^3$, well below the OSHA acceptable limit. The concentration of particles taken from the vacuumed pages ranged from 9 million particles per cubic meter to 45 million. This is also below what would be considered a toxic concentration of about 1 billion particles per cubic meter.⁴ Therefore, the exposure of Library patrons to the zinc oxide in treated books should not result in any known health effects. Whether or not these concentrations will cause other health effects depends on the results and interpretation of the animal study results.

The exposures of Library workers and plant workers to zinc oxide have not yet been measured at the time of this report.

⁴*Ibid.*, p. 4-2.

ENVIRONMENTAL IMPACT

In 1984 the Library prepared an initial environmental assessment of a proposed DEZ plant at Fort Detrick. The purpose of the assessment was to determine to what extent the siting, construction, and operation of the plant would impact the local surroundings and community. The assessment, based on the scaled-up design of the first Goddard pilot plant, determined there would be no significant impact. The assessment was reviewed and approved by Fort Detrick personnel, but the accident at Goddard halted the process before it was presented to the Army Corps of Engineers and the community for review.

The Library intends to initiate a new environmental assessment after the full-scale plant design is completed and a site has been selected. If the plant remains at Fort Detrick, as originally planned, a more comprehensive assessment than the first will be required. If another site is chosen, a new, comprehensive assessment will probably be necessary. Any ethane emissions will need to meet local air pollution regulations. Other impacts will need to be reviewed and evaluated for a new site. The Library must allow adequate time for environmental assessment to avoid delaying the construction of the plant.

DISCUSSION

OTA, with the assistance of consulting toxicologists, met with the Library's consultants, to review the studies both completed and planned. There was a general consensus that the search of the existing literature was thorough, and that there was a lack of studies directed at the effects of chronic inhalation. The planned animal study designed by the Library's consultants was also considered to be thorough and followed the accepted protocols.

There were, however, a couple of concerns expressed by OTA consultants.

There was some concern that the rat may not be an appropriate model of the human respiratory system. Rats have a greater clearance, i.e., can better remove particles from their lungs, than can humans. The amount of zinc oxide actually reaching the rat's lung (i. e., the actual dose) may be propor-

tionately far less than what would be expected to reach a human's lung. It was suggested that a pre-study test, measuring the clearance of various models including the rat, could determine the most appropriate model or at least determine the actual amount of zinc oxide getting into the rats lungs.

There are some practical limitations to using other animals too. The life span of other laboratory animals like rabbits or cats would make the chronic exposures more expensive. Some animals' lungs, such as the mouse's lung, are not sensitive enough for respiratory studies. Also there is a good inhalation database for rats. The Library analyzed this problem and concluded that it would be acceptable to use the rat model.

There was also some question as to the need for the Library to perform evaluations on the chronic effects of zinc oxide inhalation if the levels of exposure are below those experienced in the acute and

sub-chronic literature. Although there is no evidence to suggest that low levels of zinc oxide cause chronic effects or is carcinogenic, this is not sufficient to say that there are no chronic effects or that zinc oxide is not carcinogenic. Therefore, the Library and its consultants contend that it is in the Library's interest to perform a large-scale investigation into this area. It is not clear, however, whether a single study can resolve the issue. Therefore, there is a question as to how much time and effort the Library should spend in generating information that may have only a marginal value. It was suggested by one of OTA's consultants that the Library perform the exposure analysis and determine whether the levels are comparable to or below those already studied in the literature. If they are greater, then the rest of the study should be conducted. If they are below, then an extensive review of the literature and the exposure study should suffice.

