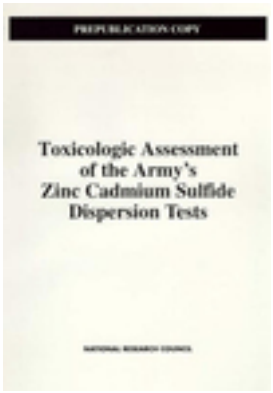

Toxicologic Assessment of the Army's Zinc Cadmium Sulfide Dispersion Tests: Answers to Commonly Asked Questions

Committee on Toxicology, National Research Council

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Toxicologic Assessment of the Army's Zinc Cadmium Sulfide Dispersion Tests: Answers to Commonly Asked Questions

SUBCOMMITTEE ON ZINC CADMIUM SULFIDE
COMMITTEE ON TOXICOLOGY
BOARD ON ENVIRONMENTAL STUDIES AND TOXICOLOGY
COMMISSION ON LIFE SCIENCES
NATIONAL RESEARCH COUNCIL

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TOXICOLOGIC ASSESSMENT OF THE ARMY'S ZINC CADMIUM SULFIDE DISPERSION TESTS: ANSWERS TO COMMONLY ASKED QUESTIONS

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BACKGROUND

During the Cold War, the United States devoted great attention to the possibility that an enemy power might attack with biologic weapons. To prepare against such an attack, the U.S. Army sponsored a variety of tests during the 1950s and 1960s to understand how biologic weapons disperse in various environments. As part of the tests, the Army released particles of zinc cadmium sulfide from airplanes, rooftops, and moving vehicles in 33 locations, mostly cities and towns, in the United States and Canada.

Zinc cadmium sulfide is not itself a biologic weapon, but it was used as a tracer to simulate the dispersion of biologic weapons in various environments. It is an inorganic compound composed of the elements zinc, cadmium, and sulfur. It glows bright yellow or green when placed under ultraviolet light, so it could easily be detected. At the time of the tests, zinc cadmium sulfide was thought to be nontoxic to humans, animals, and plants.

The zinc cadmium sulfide tests remained classified until the end of the Cold War. When the tests became public knowledge

in the early 1990s, people in cities and towns where the tests had occurred began to ask whether a variety of health problems that they or others had experienced —including cancer and infertility—were related to exposures to zinc cadmium sulfide.

In response to those concerns, Congress asked the National Research Council to determine independently whether exposures to zinc cadmium sulfide from the Army's tests had caused any adverse health effects. The National Research Council, a non-government and nonpartisan organization that examines issues of science and technology, formed a subcommittee of the Committee on Toxicology in the Board on Environmental Studies and Toxicology to conduct the study. The subcommittee consisted of 15 people from universities, laboratories, private consultants, consumer groups, risk communicators, public-health agencies, and nongovernment organizations. Members of the subcommittee were chosen for distinguished expertise in toxicology, medicine, epidemiology, chemistry, environmental health, risk assessment, and risk communication. They served without compensation as a public service.

The subcommittee has prepared this short summary report and a detailed technical report entitled *Toxicologic Assessment of the Army's Zinc Cadmium Sulfide Dispersion Tests*, which evaluates whether exposure to zinc cadmium sulfide caused adverse health effects in exposed people.

This summary report was prepared to give information to concerned citizens about zinc cadmium sulfide, especially about the human health effects that might result from exposure to it. It supplements the technical document and provides answers to commonly asked questions. It consists of three parts:

1. A background section about why the zinc cadmium sulfide tests were conducted, information on the zinc cadmium sulfide releases, and a description of the events that led up to the study of the health effects of zinc cadmium sulfide in exposed persons.

2. A section describing the sources of information considered by the National Research Council during the course of the study.
3. A series of questions most commonly asked by the public and the subcommittee's answers to those questions.

SOURCES OF INFORMATION

The subcommittee based its conclusions on two basic sources of information:

1. Information gathered at its public meetings.
2. Toxicity and exposure data on zinc cadmium sulfide, cadmium, and cadmium compounds from the open scientific literature and other technical reports.

Input from the Public

To gather information from concerned individuals and groups, the subcommittee held public meetings in three of the cities where the Army's dispersion tests had been conducted: Minneapolis, Minnesota; Fort Wayne, Indiana; and Corpus Christi, Texas.

Minneapolis and Fort Wayne were chosen because of the concerns expressed by local residents about possible health effects and the presence of community groups that were gathering information and seeking answers. Minneapolis was among the most heavily exposed cities in the Army's tests. Corpus Christi was chosen because it was a coastal city, and the subcommittee wanted to see whether anything more could be learned from the site of a coastal aerial spray. The Army had completed hazard assessments for each of the three communities. Appendix E of the subcommittee's technical report contains the announcements of the public meetings and the agendas of the meetings. Chapter 2 of

the technical report describes what transpired at the public meetings and the information obtained.

During the public meetings, the subcommittee heard from people with many different perspectives on the Army's dispersion tests. Many people were outraged about being exposed to a chemical by the government without their knowledge. They wished to ensure that testing without the informed consent of the subjects never be repeated. Several people stated that an open, thorough examination of the issues could help to restore confidence in the government. Many people attributed illnesses to the resulting exposures to zinc cadmium sulfide, including cancer, reproductive disorders, birth defects, lung disease, thyroid disorders, immunologic diseases, joint pain, infections, and skin problems. Others said that they did not know whether zinc cadmium sulfide had caused their health problems but wanted the subcommittee to have all the information available. Some people who were involved in the conduct of the dispersion tests provided information on how the tests were conducted or how samples were collected.

The views expressed at the public meetings were highly valuable to the subcommittee. They emphasized the need to consider a broad spectrum of health effects, not just cancer and infertility. They also emphasized the need to consider especially sensitive and susceptible populations, such as children and the elderly, and variations in populations and age.

It was clear from the comments and testimony presented at the public meetings that there were many questions. In many cases, some basic health information was not readily available in the community or people did not know where to go for this information. Some inquiries to local and state health agencies reportedly produced little information, and some people reported finding no one at a federal agency available to respond to their questions. The subcommittee's conclusions, which are summarized in this brief report, reflect long and careful consideration of all the issues, questions, and suggestions raised at the public meetings. Answers to technical questions most commonly asked of the sub

committee by the public are provided below. The subcommittee did not address ethical issues about the Army's dispersion tests; this question is important but was beyond the subcommittee's charge and expertise.

Open Scientific Literature and Other Technical Reports

The subcommittee was provided with the current Army files relevant to the zinc cadmium sulfide dispersion tests. The Army informed the subcommittee in a letter (see Appendix C of the subcommittee's technical report) that all relevant information had been declassified and made available to it. The subcommittee also had access to published and unpublished literature on zinc cadmium sulfide —reports available in the open scientific literature; reports from Stanford University and the Ralph Parsons Company (the Army's contractors for the zinc cadmium sulfide dispersion tests); material-safety data sheets; and Army reports. In addition, the subcommittee reviewed toxicity data and exposure data on cadmium (the most-toxic component of zinc cadmium sulfide), zinc, and other minor components of zinc cadmium sulfide.

The subcommittee became aware that some of the exposure data from the Army's tests on zinc cadmium sulfide are missing. The Army was asked to supply the missing data, and it informed the subcommittee that it was unable to find those data because the information being sought is 30–40 years old, and the data on the Army's dispersion tests had not been cataloged. However, the subcommittee feels confident about the large amount of data that it did review and does not believe it likely that the missing data would alter its conclusions.

QUESTIONS AND ANSWERS

On the basis of a thorough review of the open scientific literature, other technical reports, the statements and materials pre

sented at the public meetings, and the expertise of its members, the subcommittee offers the following responses to questions most commonly asked by the public.

1. What is zinc cadmium sulfide, and why was it used in the Army's dispersion tests?

Zinc cadmium sulfide is a fine powder that is formed by heating zinc sulfide and cadmium sulfide together under very high temperatures (about 1,650° F) so that they fuse. The fused compound is an alloy that does not contain pure zinc sulfide or cadmium sulfide, because the fusing process is highly efficient.

Zinc cadmium sulfide was the compound that was dispersed over Minneapolis, Fort Wayne, Corpus Christi, and many other locations in the United States and Canada to obtain information that the Army used to estimate the potential dispersion of biologic weapons in various environments and to determine the quantity required for the strategic use of biologic weapons. Zinc cadmium sulfide is not a biologic weapon; it was a tracer used by the Army to imitate or simulate the dispersion of biologic weapons. The Army chose zinc cadmium sulfide for several reasons. First, particles of zinc cadmium sulfide are about the same size (average size, 2–3 μm; 1 μm is one millionth of a meter) as microorganisms (germs), so they would be expected to disperse in the atmosphere in approximately the same way. Second, toxicity tests (although limited) did not indicate that zinc cadmium sulfide would be harmful to humans. Third, because they fluoresce under ultraviolet light, the zinc cadmium sulfide particles could be traced and counted. Fourth, the compound is stable in air and water; it dissolves slightly only in strong acids. Fifth, it is inexpensive.

In the 1950s and 1960s, zinc cadmium sulfide was also used as a pigment in paints and as a fluorescent material for television screens and other reflective materials. It is no longer used or manufactured in this country, because better materials are available.

2. How does zinc cadmium sulfide enter the environment, and how might I have been exposed to it?

Zinc cadmium sulfide does not occur naturally in the air, in water, or on the earth's surface. Some reports say that it might occur deep in the earth's crust as a result of volcanic activity. Small amounts entered the environment from the Army's dispersion tests when it was released from airplanes, towers, rooftops, and moving vehicles. The Army stopped the dispersion tests in the 1960s.

When a substance is released into the environment, the release does not always result in exposure of people. You are exposed to a substance only when you come into contact with it. As a result of the Army's dispersion tests, you might have had contact by breathing air, by eating food, by drinking water containing zinc cadmium sulfide, or by skin contact.

3. What happens to zinc cadmium sulfide when it enters the environment?

Little is known about how it accumulates and moves through the environment. Over a long time, it probably breaks down into zinc sulfide and cadmium sulfide, from which it was made, and other materials. There is no information available on the buildup of zinc cadmium sulfide in plants or whether it builds up in fish and animals that come into contact with it through air, water, soil, or food containing zinc cadmium sulfide.

4. How much and how often might I have been exposed to zinc cadmium sulfide?

The subcommittee reviewed the zinc cadmium sulfide exposure data from the Army's files. The highest estimated potential exposure doses reported for individuals were in Minneapolis (44 μg), Winnipeg, Canada (93 μg), St. Louis, Missouri (156 μg), and Biltmore Beach, Florida (2,500 μg). One microgram (μg) is

one millionth of a gram; one gram is one four hundred forty-fourth (1/444) of a pound. Because cadmium represents 15.6% of zinc cadmium sulfide by weight, multiplication of the potential zinc cadmium sulfide doses by 0.156 yields the corresponding cadmium doses from the Army's tests. Thus, the corresponding highest estimated potential cadmium doses were 6.8 µg, 14.5 μg, 24.4 μg, and 390 μg, respectively. Most people were exposed to much lower doses. The frequency of exposure to zinc cadmium sulfide varied from location to location. Some locations were exposed once or a few times; other locations were exposed up to 35 times over a period of two years. For further information on potential zinc cadmium sulfide doses in other test locations, see Appendix B of the subcommittee's technical report.

5. How can zinc cadmium sulfide enter and leave my body?

Because zinc cadmium sulfide does not dissolve in water or fats and dissolves only slightly in strong acids, it is not likely that it can pass through your skin if you touch it or enter your bloodstream if you take in air, food, or water that contains it. If you swallow zinc cadmium sulfide, it will most likely pass through your body and be excreted in feces. Just like other dust particles in air, particles of zinc cadmium sulfide are likely to deposit in your lungs if you breathe air that contains it; and this is the main way that you might have been exposed to zinc cadmium sulfide from the Army's dispersion tests. Most of the inhaled zinc cadmium sulfide would be expected to be exhaled, and only a small percentage of it would be deposited in the lungs. However, most of the deposited zinc cadmium sulfide would be cleared from your lungs like other dust particles by normal pulmonary clearing mechanisms.

6. How can zinc cadmium sulfide affect my health?

When you are exposed to a particular substance, many factors determine whether harmful health effects occur and what

kinds and how serious they will be. Those factors include the toxicity of the substance, the dose (how much), the duration (how long), the pathway or route by which you are exposed (breathing, eating, drinking, or skin contact), the other chemicals to which you are exposed, and your individual characteristics, such as age, sex, nutritional status, family traits, and state of health.

Although more is known about some related chemicals, it is not well known how the compound zinc cadmium sulfide could affect people's health. There is little information on the toxicity of zinc cadmium sulfide in experimental animals. We do know that animals that were fed massive amounts of zinc cadmium sulfide one time did not show any ill health effects. We also know that zinc cadmium sulfide does not irritate rabbits' skin or eyes.

Information is not available on whether particles of zinc cadmium sulfide that might become lodged in your lungs for a long time are harmful. The subcommittee has recommended that research be done to find out whether those particles might break down in the lungs into toxic materials that could enter the bloodstream. The Army is now doing the recommended research.

Cadmium is the most toxic component of zinc cadmium sulfide. Zinc cadmium sulfide cannot be more toxic than soluble cadmium compounds, so toxicologic assessment assuming soluble cadmium compounds represents the worst-case scenario.

Cadmium is a natural component of the earth's crust. All soils and rocks, including coal, have some cadmium in them. Humans are exposed to cadmium naturally through water, air, food, soil, and house dust. Cadmium enters the air from the burning of coal and household waste. In the United States, mean concentrations of cadmium in ambient air range from less than 0.001 $\mu g/m^3$ in remote areas to 0.005–0.04 $\mu g/m^3$ in urban areas. Atmospheric concentrations of cadmium are generally highest in the vicinity of cadmium-emitting industries such as smelters, municipal incinerators, or fossil-fuel combustion facilities. Measurements of atmospheric cadmium up to 7 $\mu g/m^3$ have been reported in these industrial types of areas in the United States. Cadmium intake from air is estimated to be 0.1–0.8 μg per day in typical

U.S. urban cities and less than 0.02 μg per day in rural areas.

Food is the largest potential source of cadmium exposure for the general population. The daily cadmium intake from food in the United States ranges from 10 to 60 μg.

Except in the vicinity of cadmium-emitting industries, the concentration of cadmium in most U.S. drinking-water supplies is less than 1 μg/L. However, concentrations of up to 10 μg/L have been reported in some water supplies. Thus, daily cadmium intake from drinking water is about 2–20 μg, assuming that a person drinks 2 liters of water per day.

Cigarettes are also an important source of cadmium exposure. The amount of cadmium that can be inhaled from smoking one cigarette is 0.1–0.2 μg. Thus, it can be estimated that someone smoking one pack per day will take in 2–4 μg of cadmium per day.

The highest estimated cadmium intake from the zinc cadmium sulfide dispersion tests was 24.4 μg in St. Louis, 14.5 μg in Winnipeg, 6.8 μg in Minneapolis, 1.1 μg in Fort Wayne, and 0.1 μg in Corpus Christi.

The subcommittee concluded that the amounts of cadmium from the zinc cadmium sulfide used in the Army's dispersion tests were well below the amounts at which toxic effects occur. For most of the people living in the most heavily exposed populated area—St. Louis—the highest estimated airborne exposure to cadmium (24.4 μg) was equivalent to what urban residents would typically experience from inhaling air over the course of 1—8 months. For people living in Fort Wayne, the highest estimated exposure to cadmium (1.1 μg) was equivalent to what urban residents would typically experience from inhaling air over the course of 1–11 days. For people living in Minneapolis, the highest estimated exposure to cadmium (6.8 μg) was equivalent to what urban residents would typically experience from inhaling air over the course of 1–10 weeks. As a result, the subcommittee has concluded that given the very small amounts of zinc cadmium sulfide to which people were exposed and the short duration of exposure, it is extremely unlikely that anyone in the test areas

developed adverse health effects, such as lung cancer or infertility problems, from the Army's releases of zinc cadmium sulfide.

7. What is the effect of repeated exposure to zinc cadmium sulfide?

There have been no studies on the toxic effects of repeated exposure to zinc cadmium sulfide. If we assume a worst-case scenario—that exposure to zinc cadmium sulfide will have the same effect as exposure to an equivalent amount of cadmium—then repeated exposures to zinc cadmium sulfide could cause kidney and bone toxicity and lung cancer. However, exposures from the Army's zinc cadmium sulfide tests involved small amounts for short duration; therefore, such effects are highly unlikely.

8. Are any members of the population especially sensitive to zinc cadmium sulfide?

Differences in sensitivity to zinc cadmium sulfide have not been studied. It is extremely unlikely that zinc cadmium sulfide could enter the bloodstream of any person, including sensitive people, such as infants, children, and the elderly, from exposure of the skin, lungs, or digestive tract. That is because zinc cadmium sulfide does not dissolve in water or fats, and it dissolves only slightly in strong acids. Therefore, it is not likely to pass through the skin or enter the bloodstream if it is swallowed in food or water containing it. On the basis of the available data, if people, including sensitive people, swallow zinc cadmium sulfide, it will most likely pass through their bodies and be excreted in their feces. Like other dust particles in air, particles of zinc cadmium sulfide are likely to deposit in the lungs of all individuals, including sensitive people, if they breathe air contaminated with it. Most of the inhaled zinc cadmium sulfide will be exhaled, and only a small percentage of it will be deposited in the lungs. Most of the deposited zinc cadmium sulfide will be cleared from

the lungs by normal pulmonary clearing mechanisms. Because of these factors, we do not expect members of sensitive populations to have greater harmful effects from exposure to zinc cadmium sulfide. However, as a precautionary measure, the subcommittee assumed in its risk estimates for cancer and other health effects that sensitive subpopulations might be 10 times more sensitive than healthy adults.

9. Would there be any potential adverse health effects passed on to children born to people who were exposed to zinc cadmium sulfide?

The subcommittee did not identify any information showing that exposure to zinc cadmium sulfide could have caused adverse health effects in the children of exposed people. The subcommittee's review of available developmental toxicity data on cadmium (the most toxic component of zinc cadmium sulfide) shows that it is extremely unlikely that children of exposed mothers would show signs of developmental toxicity at the low levels encountered as a result of the Army's dispersion tests.

10. How do I know if I have been exposed to zinc cadmium sulfide?

No medical test is available to determine whether you were exposed to zinc cadmium sulfide. However, you can be tested for exposure to cadmium in several ways. The amount of cadmium in your blood, urine, hair, or nails can be measured by some medical laboratories. The amount of cadmium in your blood tends to show your recent exposure to cadmium. The amount in your urine tends to indicate both your recent and past exposures. However, a finding of exposure to cadmium does not mean that you were exposed to zinc cadmium sulfide, because people are exposed naturally to cadmium from air, food, and water. The subcommittee concluded that an increase in cadmium in the body above the typical background concentrations could not be attrib

uted to the Army's zinc cadmium sulfide dispersion tests, because the exposures occurred more than 30 years ago, and the concentrations in most cases were below the background concentrations encountered in urban areas.

11. Is it possible to conduct an epidemiologic study of zinc cadmium sulfide-exposed persons?

Many people in the test areas have asked whether it is possible to look for health effects in people who might have been exposed during the tests. However, several problems make such studies unfeasible. The diseases reported by people at the public meetings occur often in human populations, and it is very difficult to pinpoint the exact cause of these diseases. After 30–40 years, it would be very hard to identify the people who were exposed or affected and to determine their past exposures to zinc cadmium sulfide. Even if the exposed people could be identified, even a large epidemiologic study would not be able to distinguish the health effects of zinc cadmium sulfide from those associated with other factors, such as breathing cadmium in typical urban air for a few weeks.

12. Were biologic materials used in the Army's testing program?

Review of the Army's files related to the zinc cadmium sulfide dispersion tests showed that in several cases tests were also conducted with microorganisms—such as *Serratia marcescens, Bacillus globigii*, or some species of *Aspergillus* (fungus or mold)—either alone or with zinc cadmium sulfide. All those organisms were considered by the Army to be safe at the time of their use. Relatively recent research has indicated that those microbes do not produce disease in healthy people, but some could cause disease in persons whose immune (body-defense) system is weak. Although some of the Army's tests involved exposures to zinc cadmium sulfide at the same time as microorganisms, such

as *Serratia marcescens*, the subcommittee did not assess the implications of such coexposures, because that was beyond its charge and ability.

13. Where can I go for more information?

If you have any more questions or concerns, please see the full technical report of the Subcommittee on Zinc Cadmium Sulfide. The report, entitled *Toxicologic Assessment of the Army's Zinc Cadmium Sulfide Dispersion Tests*, can be obtained from the National Academy Press, 2101 Constitution Avenue, NW, Washington, DC 20418, telephone (202) 334-3313 or (1–800) 624-6242. The report contains a full analysis of the toxicity and exposure data on zinc cadmium sulfide and cadmium. It has eight chapters, nine appendixes, and a glossary of technical terms used. Chapter 1 describes the background of the study and structure of the report. Chapter 2 presents the information gathered from the public meetings. Chapter 3 reviews the toxicity and related data on zinc cadmium sulfide, and Chapter 4 evaluates the toxicity, environmental fate, and epidemiology data for cadmium compounds. Chapter 5 evaluates the exposures to zinc cadmium sulfide and cadmium, and Chapter 6 contains the subcommittee's risk assessments of zinc cadmium sulfide for noncancer and cancer effects. Chapter 7 discusses the feasibility of conducting epidemiologic studies of zinc cadmium sulfide-exposed persons. Chapter 8 contains the subcommittee's conclusions and recommendations. Appendix A provides a historical background of the U.S. biologic-warfare program. Appendix B shows the doses and concentrations of zinc cadmium sulfide measured in various cities after the Army's dispersion tests. Appendix C contains correspondence between the Army and the National Research Council about the declassification of all relevant data on the zinc cadmium sulfide tests. Appendix D discusses the toxic interaction of zinc and cadmium. Appendix E provides information about the public meetings. Appendix F provides information on the sampling and analytic methods used in the zinc cadmium sulfide tests. Appen

dix G contains the subcommittee's review of the Army Environmental Hygiene Agency's risk-assessment reports. Appendix H reviews the comments of the U.S. Environmental Protection Agency, the Centers for Disease Control and Prevention and the Agency for Toxic Substances and Disease Registry on the Army's risk-assessment reports. Appendix I contains the cadmium exposure assessment.

This public report is available on the Internet at http://www.nap.edu/readingroom/enter2.cgi?030905799X.html