Estimated Possible Effects of AgI Cloud Seeding on Human Health

RONALD B. STANDLER[1] AND BERNARD VONNEGUT[2]

State University of New York at Albany 12222

20 June 1972 and 11 August 1972

ABSTRACT

Estimates based on information in medical and meteorological literature indicate that AgI in the air and in precipitation does not pose a danger to people in the target area. Although the concentration of AgI near the generator is much larger, interviews with operators who have been seeding on a large scale for many years fail to disclose any instances of ill effects from AgI.

1. Introduction

Concern has been expressed (Sargent, 1969) about the possible dangers resulting from the widespread introduction into the atmosphere of AgI particles for the purpose of cloud seeding. Battan (1962) has stated, "silver iodide is toxic and must be handled with care." Because the danger to man depends in a complicated way on such poorly evaluated variables as the concentration of silver and iodine, and the response of living materials to these substances, it is not possible to give an unequivocal answer to the question of environmental effects of AgI cloud seeding. Enough information is available, however, to make estimates.

We will consider several ways human beings might be affected by AgI cloud seeding: drinking water containing AgI cloud seeding material, breathing the AgI aerosol, and handling the concentrated AgI solution used in the generator.

2. Toxicity of AgI to man

Our knowledge of the effects produced by AgI on the human body is derived primarily from the experience in the 1930's when, on physicians' recommendation, many patients used as nasal sprays a 1–4% colloidal suspension of AgI. While there is no evidence that occasional use of this medication produced adverse effects, prolonged usage resulted in a permanent generalized ashen pigmentation of the skin (argyria) as the result of the deposition of silver. The medical literature contains reports of 17 patients who developed argyria after using AgI at least several times a week for several years (Royster, 1932; Lundy, 1933; Woodward, 1933; Berkley, 1934; Gaul and Staud, 1935; Hill and Pillsbury, 1939; Brinton, 1949; Gerbasi and Robinson, 1949). We estimate that the patients who developed argyria used a total quantity of AgI ranging from at least 2 gm to about 50 gm. It is important to note that there were no adverse effects due to AgI reported for any patients except argyria, a condition which, while regrettable, is "of significance only from the standpoint of cosmetic appearance" (Hill and Pillsbury, 1939).

The biological effects of AgI, unlike those of many compounds, seem to be primarily those of one of its elemental constituents, silver. The maximum allowable concentration of silver in drinking water is 50 ng ml^{-1} (Public Health Service, 1962). This figure is derived from the assumption that a total intake of silver in any form in excess of 0.9 gm may produce argyria (Hill and Pillsbury, 1939). One should note that 0.9 gm is the amount of silver that may produce argyria when taken in addition to the background concentration of silver ingested in the diet and from miscellaneous sources such as silverware, coinage, and dental fillings. The American Conference of Governmental Industrial Hygienists has recommended that the maximum allowable concentration of silver in air be 10 $\mu g\ m^{-3}$ (Sax, 1968). We do not expect that ill effects due to iodine in AgI will be as important as those due to silver, partly because adverse effects due to iodine in the AgI nasal spray were not reported, and partly because iodine is essential to the human diet. The recommended dietary allowance of iodine for adults is between 100 and 150 $\mu g\ day^{-1}$ (Holvey, 1972). Over the lifetime of a 70 year old man, the total recommended dietary intake of iodine would be 3 gm. Studies show that chronic ingestion of iodide by human beings at a much larger rate of at least 18 mg day^{-1} induces goiter (Wolff, 1969). The concentration of iodine in maritime air is about 1 ng m^{-3} (Duce *et al.*, 1967); the maximum allowable concentration of iodine in air has been given as 1 mg m^{-3} (Sax, 1968).

AgI is not listed as being poisonous in the references on toxicology. It has been stated that because of the low

[1] Department of Atmospheric Science. Present affiliation: Department of Physics, New Mexico Institute of Mining & Technology, Socorro.

[2] Atmospheric Sciences Research Center.

Unauthenticated | Downloaded 06/17/24 02:59 AM UTC

solubility of AgI in water, ~3 ng ml^{-1} (Linke and Seidell, 1958), the compound is "essentially non-toxic" (Deichmann and Gerarde, 1958). One reference lists the dangerous properties of AgI merely as those of a silver salt (Sax, 1968), while another fails to include toxicity information on this compound (Stecher, 1968). It would appear from the foregoing data that AgI does not represent an outstanding hazard to human health.

Many generators employ solutions containing one-half mole of either NaI or KI to each mole of AgI to increase its solubility in acetone (Vonnegut, 1950). These will release sodium or potassium into the atmosphere in addition to AgI (de Pena and Caimi, 1967). The concentrations of these common alkali elements released by cloud seeding are trivial compared to those already present in man and his environment and can, therefore, be safely neglected.

3. AgI in precipitation

We can evaluate the concentration of silver in water from cloud seeding by considering the theoretical expectation and measurements of the concentration of silver in precipitation. If single AgI particles of size 1.0–0.02 μm serve as nuclei for raindrops of 1 mm diameter, we can expect resultant concentrations of silver in rainwater from 5 ng ml^{-1} to 0.04 pg ml^{-1}.

To evaluate the amount of silver introduced into precipitation by AgI cloud seeding we must, of course, determine the extent to which the concentration of silver in precipitation from seeded clouds exceeds the background concentration measured in precipitation from unseeded clouds. One would expect that, after adding AgI to a cloud, the precipitation from it would contain more silver than from an unseeded cloud. This is supported by most measurements. Warburton and Maher (1965) found concentrations of silver in rain from seeded clouds which ranged from 48 pg ml^{-1} to less than 2 pg ml^{-1}, the average of 63 samples being ~7 pg ml^{-1}. The amount of silver was undetectable in all but 3 of 23 samples of rain from unseeded clouds; one of these "high" concentrations was explained as contamination at the collection site. Silver could not be detected in samples of snow collected in a region where AgI cloud seeding was not conducted; the concentration was probably less than 10 pg ml^{-1} (Warburton and Young, 1968).

The background concentration of silver is not always found to be negligible: Parungo and Robertson (1969) found that the background in their samples was about 13% of the average concentration in seeded samples. They reported an average concentration of silver in snow from seeded clouds to be 0.95 ng ml^{-1}, with values ranging from 8.0 to less than 0.01 ng ml^{-1} in 73 samples. Nineteen determinations of silver in unseeded snow yielded concentrations which ranged from 1.2 to less than 0.01 ng ml^{-1}.

The expected relationship between concentrations in seeded and unseeded precipitation was reversed in one case. During the 1966 Project Hailswath the average concentration of silver in unseeded precipitation was 180 pg ml^{-1}, twice the concentration found in precipitation from seeded areas (Warburton and Young, 1968). These occasional anomalous background values may originate because supposedly natural precipitation may actually have been contaminated by some unrecognized seeding operation, or silver may have been inadvertently introduced during collection and laboratory procedures.

Although the experimental data spans four orders of magnitude, it is still consistent with theoretical estimates made earlier. Hence, they can serve as a reasonable basis on which to estimate the possible toxic effects from AgI cloud seeding. The maximum reported concentration is a factor of 6 below the maximum allowable concentration set by the U. S. Public Health Service for silver in drinking water. It is clear that a person could drink water produced as a result of AgI cloud seeding exclusively throughout his lifetime without risking argyria.

A different perspective for evaluating the possible contamination of the earth's water by AgI cloud seeding is afforded by considering the amount of silver and iodine already present in the ocean. The concentration of silver in stream and ocean water is about 0.3 ng ml^{-1} (Kharkar *et al.*, 1968; Schutz and Turekian, 1965), and the concentration of iodine in the ocean is about 50 ng ml^{-1} (Sverdrup *et al.*, 1942). There is a reservoir of about 4×10^{15} gm of silver in the ocean, which is much larger than the annual world production of silver—only 8×10^{9} gm year^{-1} (Long, 1968). We can see that the entire global production of silver could be added to the ocean for 5×10^{5} years before the present concentration would be doubled. This, of course, does not imply that levels of silver that might cause concern could not develop in localized areas. Because iodine is much more plentiful than silver in the ocean, we are not concerned about the addition of iodine to the ocean by AgI cloud seeding.

4. AgI in air

People will also take in AgI by breathing air containing particles from generators. We can estimate the concentration downwind in the target area from the calculation that 5×10^{4} nuclei m^{-3} produce dramatic changes in a supercooled cloud (Jiusto, 1971). If we assume 0.1 μm size AgI particles, this yields a concentration of silver in air of 0.1 ng m^{-3}. This is a factor of 10^{5} below the maximum allowable concentration and should not be a cause for concern. The margin of safety is not nearly as large at the generator site, where, before mixing and diluting, the concentration of AgI will be many orders of magnitude greater. It can be calculated that the AgI aerosol will not be diluted by mixing to the maximum permissible concentration of silver discussed earlier until the aerosol has been carried at least 50 m downwind from a generator emitting silver at a rate of 1 mg sec^{-1} in a 6° plume in a 5 m sec^{-1} wind.

Unauthenticated | Downloaded 06/17/24 02:59 AM UTC

5. Untoward effects in generator operators

If AgI cloud seeding were to produce untoward effects in human beings, these ill effects should appear in people who operate AgI generators long before symptoms appear in the general public. To investigate this we interviewed by telephone seven cloud seeding operators (Eugene Bollay, Robert Elliott, Lewis Grant, Thomas Henderson, Wallace Howell, Irving Krick, Gerald Smith) who have had extensive experience with AgI. None knew of any person who had suffered ill effects due to AgI. The remarks of Howell are worth quoting: ". . . I've gone with my hands yellow with it [AgI] for weeks at a time, and I certainly don't have argyria, and none of the people that I've worked with have ever reported any symptoms."

We are aware of only two cases in which untoward effects were attributed to AgI aerosol. One of us (B. V.) recalls that in New Mexico in the early 1950's a technician claimed that breathing AgI from a ground based generator aggravated his respiratory allergy. This individual may well have been sensitive to any particulate matter; therefore, his reaction alone does not necessarily incriminate AgI. In another instance Douglas (1970) has stated that an individual who remained within a few meters of a generator for 6 hr "suffered a skin rash which, while inconvenient, was not serious enough to cause loss of work."

6. AgI on skin

Technicians risk exposure to large amounts of AgI when handling concentrated AgI solutions. AgI imparts a yellow stain to the outer layers of the skin, which has not been reported to cause injurious effects. Unlike argyria, the yellow stain is superficial and will gradually disappear after the individual's skin is no longer exposed to AgI.

7. Inhalation of acetone

Henderson told us that he was more concerned about generator operators breathing the acetone from the unignited AgI solution than about possible poisoning from AgI itself. While references on toxicology mention that inhalation of the pungent acetone vapor can cause headaches and drowsiness, "serious poisoning is rare" (Stecher, 1968). Reports of six patients who developed acute acetone poisoning by inhaling the solvent used in plastic casts indicate that some people are highly sensitive to acetone so that concern appears justified (Strong, 1944; Chatterton and Elliot, 1946; Fitzpatrick and Claire, 1947; Pomerantz, 1950; Harris and Jackson, 1952; Renshaw and Mitchell, 1956).

8. Effects on other organisms

We have not attempted to assess the biological effects of AgI on organisms other than human beings. Cooper and Jolly (1970) have suggested that silver will be more toxic to algae, fungi, bacteria and fish than to man. In addition, Gerald Smith has mentioned to us that although the leaves of a peach tree 8 m downwind from an AgI generator turned black and the tree bore no fruit, it returned to normal the following year. He suggested this might have been a result of sulfur in the coke fuel rather than AgI.

9. Conclusions

Although there appears to be no immediate reason for believing that AgI is causing harmful biological effects, consideration should be given to other possible cloud seeding agents that might pose even smaller hazards to health or ecology. It is worth pointing out that any assessment of the possible dangers from the seeding agent involves not only the toxicity of the agent, but also the size of the particles that must be dispersed into the atmosphere to serve as nuclei. For example, if particles of a substance must be 10 μm in diameter in order to nucleate ice, 1 ton of this material must be dispersed into the atmosphere to produce the same effect obtainable with 1 gm of AgI dispersed as 0.1 μm particles. It is possible that, even if such a substance were less toxic, the fallout of the large amounts that would be required could cause more damage than that which would result from a much smaller amount of AgI.

In summary, we present the following conclusions and recommendations:

1) On the basis of presently available information, there appears to be no danger in drinking water or breathing air in the target area.

2) Although no ill effects have been reported by generator operators, further studies are desirable to determine the hazards associated with inhaling AgI aerosols.

3) More biological studies are needed to determine the effects of AgI on vegetation, fish, and other organisms.

4) Any person knowing of argyria or other symptoms resulting from AgI cloud seeding is encouraged to publish this information as a guide and warning to others.

Acknowledgments. We thank Eugene Bollay, Robert Elliot, Lewis Grant, Thomas Henderson, Wallace Howell, Irving Krick and Gerald Smith for their kind cooperation in describing their experiences with AgI cloud seeding, which are cited in this paper. The research reported in this paper was sponsored in part by the Air Force Cambridge Research Laboratories, Air Force Systems Command, under Contract F19628-68-C-0057, and in part by the Office of Naval Research, under Contract N00014-71-C-0156. This report does not necessarily reflect endorsement by the sponsors.

REFERENCES

Battan, L. J., 1962: *Cloud Physics and Cloud Seeding.* New York, Doubleday, 144 pp.

Berkley, H. K., 1934: Argyria. *J. Amer. Med. Ass.*, **102**, 202–203.

Brinton, W. D., 1949: Argyria: Report of a case. *Guy's Hosp. Rept.*, **98**, 88–94.

Unauthenticated | Downloaded 06/17/24 02:59 AM UTC

Chatterton, C. C., and R. B. Elliott, 1946: Acute acetone poisoning from leg casts of a synthetic plaster substitute. *J. Amer. Med. Ass.*, **130**, 1222–1223.

Cooper, C. F., and W. C. Jolly, 1970: Ecological effects of silver iodide and other weather modification agents: A review. *Water Resources Res.*, **6**, 88–98.

Deichmann, W. B., and H. W. Gerarde, 1958: *Signs, Symptoms and Treatment of Certain Acute Intoxications*, 2nd ed. Springfield, Thomas, 154 pp.

Douglas, W. J., 1970: Silver iodide generators and public health. *J. Irrig. Drain. Div. ASCE*, **96**, 273–280.

Duce, R. A., A. H. Woodcock and J. L. Moyers, 1967: Variation of ion ratios with size among particles in tropical oceanic air. *Tellus*, **19**, 369–379.

Fitzpatrick, L. J., and A. C. Claire, 1947: Acute acetone poisoning. *Anesth. Analg.*, **26**, 86–87.

Gaul, L. E., and A. H. Staud, 1935: Clinical spectroscopy. *J. Amer. Med. Ass.*, **104**, 1387–1390.

Gerbasi, F. S., and A. R. Robinson, 1949: Excretion of silver in a patient with argyrosis. *Amer. J. Clin. Path.*, **19**, 668–675.

Harris, L. C., and R. H. Jackson, 1952: Acute acetone poisoning caused by setting fluid for immobilizing casts. *Brit. Med. J.*, **2**, 1024–1026.

Hill, W. R., and D. M. Pillsbury, 1939: *Argyria*. Baltimore, Williams and Wilkins, 172 pp.

Holvey, D. N., Ed., 1972: *The Merck Manual*, 12th ed. Rahway, Merck, 1964 pp.

Jiusto, J. E., 1971: Crystal development and glaciation of a supercooled cloud. *J. Rech. Atmos.*, **5**, 69–85.

Kharkar, D. P., K. K. Turekian and K. K. Bertine, 1968: Stream supply of dissolved silver, molybdenum, antimony, selenium, chromium, cobalt, rubidium, and cesium to the oceans. *Geochim. Cosmochim. Acta*, **32**, 285–298.

Linke, W. F., and A. Seidell, 1958: *Solubilities*, 4th ed. Washington, D. C., Amer. Chem. Soc., 1487 pp.

Long, L. H., Ed., 1968: *The World Almanac*. New York, Newspaper Enterprise, 932 pp.

Lundy, C. J., 1933: Argyria. *Ill. Med. J.*, **63**, 173.

Parungo, F. P., and C. E. Robertson, 1969: Silver analysis of seeded snow by atomic absorption spectrophotometry. *J. Appl. Meteor.*, **8**, 315–321.

de Pena, R. G., and E. A. Caimi, 1967: Hygroscopicity and chemical composition of silver iodide smoke used in cloud seeding experiments. *J. Atmos. Sci.*, **24**, 383–386.

Pomerantz, R. B., 1950: Acute acetone poisoning from castex. *Amer. J. Surg.*, **80**, 117–118.

Public Health Service Drinking Water Standards, 1962: Washington, D. C., Govt. Print. Off., 61 pp.

Renshaw, P. K., and R. M. Mitchell, 1956: Acetone poisoning following the application of a lightweight cast. *Brit. Med. J.*, **1**, 615.

Royster, L. T., 1932: Argyria. *J. Pediat.*, **1**, 736–738.

Sargent, F., 1969: Weather modification and the biosphere. *Tech. Rev.*, **71**, 42–47.

Sax, N. I., 1968: *Dangerous Properties of Industiral Materials*, 3rd ed. New York, Reinhold, 1251 pp.

Schutz, D. F., and K. K. Turekian, 1965: The investigation of the geographical and vertical distribution of several trace elements in sea water using neutron activation analysis. *Geochim. Cosmochim. Acta*, **29**, 259–313.

Stecher, P. G., Ed., 1968: *The Merck Index*, 8th ed. Rahway, Merck, 1713 pp.

Strong, G. F., 1944: Acute acetone poisoning. *Can. Med. Ass. J.*, **51**, 359–362.

Sverdrup, H. U., M. W. Johnson and R. H. Fleming, 1942: *The Oceans: Their Physics, Chemistry, and General Biology*. New York, Prentice-Hall, 1087 pp.

Vonnegut, B., 1950: Techniques for generating silver iodide smoke. *J. Colloid Sci.*, **5**, 37–48.

Warburton, J. A., and C. T. Maher, 1965: The detection of silver in rainwater: Analysis of precipitation collected from cloud-seeding experiments. *J. Appl. Meteor.*, **4**, 560–564.

— —, and L. G. Young, 1968: Neutron activation measurements of silver in precipitation from locations in western North America. *J. Appl. Meteor.*, **7**, 444–448.

Wolff, J., 1969: Iodide goiter and the pharmacologic effects of excess iodide. *Amer. J. Med.*, **47**, 101–124.

Woodward, M. R., 1933: Argyria from the use of colloidal silver iodide intranasally. *Amer. J. Dis. Child.*, **45**, 1046–1049.

Unauthenticated | Downloaded 06/17/24 02:59 AM UTC