NOAA Technical Memorandum EDS ESIC-2

U.S. DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
Environmental Data Service

An Annotated Bibliography on the Biological and Physiological Effects of Silver Iodide Cloud Seeding, 1962-1971

ANNIE E. GRIMES

Environmental Science Information Center
ROCKVILLE, MD.
June 1972

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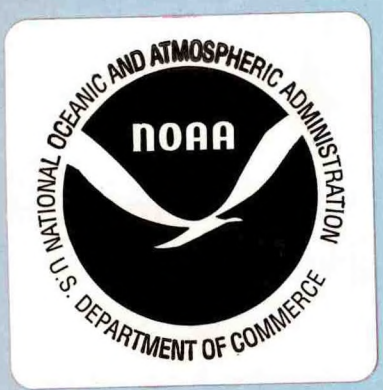

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AN ANNOTATED BIBLIOGRAPHY ON THE BIOLOGICAL AND PHYSIOLOGICAL EFFECTS OF SILVER IODIDE CLOUD SEEDING, 1962 - 1971

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016	Subject bibliographies
546	Inorganic chemistry
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551.5	Meteorology
.509.617	Cloud and precipitation modification
614	Public health
.7	Air, soil and water pollution
"1962/1971"	1962-1971

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INTRODUCTION

This bibliography on the biological and physiological effects of silver iodide cloud seeding has been compiled from references in the Atmospheric Sciences Library. So far, all aspects of silver iodide effects have not been evaluated in the literature, therefore references are also presented on (1) silver concentration in various forms of precipitation, (2) residual effect or persistence of silver iodide in the seeded area, (3) toxicity of materials used in silver iodide cloud seeding, and (4) composition and properties of silver iodide smoke.

The papers for references 13, 17, 22, 32, and 36 are not available in the Atmospheric Sciences Library. Abstracts for references 17, 32, and 36 have been located in this library; they have been included in this bibliography.

The call number for the Atmospheric Sciences Library follows the symbol DAS in the citation.

The symbol MGA appearing at the end of an abstract indicates that the abstract was taken from the "Meteorological and Geoastrophysical Abstracts" of the American Meteorological Society.

AN ANNOTATED BIBLIOGRAPHY ON THE BIOLOGICAL AND PHYSIOLOGICAL EFFECTS OF SILVER IODIDE CLOUD SEEDING, 1962 - 1971

References and Abstracts

1. Atmospheric Water Resources Research, 1968. Supplemental final report. Fresno State College Foundation. Bureau of Reclamation Contract No. 14-06-D-5819. (In: U. S. Office of Atmospheric Water Resources. Project Skywater: Atmospheric Water Resources Program; Annual Report 1968. Contractor Reports. pp. 59-80) DAS M09.617 U586pr 1968.

   In Section D the effectiveness of silver iodide dispensing techniques and the amounts of dispersion of AgI experienced in various areas of the Sierra Nevada mountains of California are briefly discussed. In the Southern Sierra the maximum concentration found in a snow sample was 5.2×10^{-10} grams per milliliter. The minimum amount measured in the Fresno area did not exceed 7.9×10^{-12} grams per milliliter and the median concentration was 318×10^{-11}.

2. Bollay, (E.) Associates, Inc. Park Range atmospheric water resources program. September 1968. Interim Report. Bureau of Reclamation, Contract No. 14-06-D-5640. (In: U. S. Office of Atmospheric Water Resources. Project Skywater: Atmospheric Water Resources Program; Annual Report 1968. Contractor Reports. pp. 267-284) DAS M09.617 U586pr 1968.

   In FY 68 winter season 781 snow samples were collected in the Steamboat, Colorado area. Most of them were analyzed by an atomic absorption spectrophotometer for Ag mass concentration values. The range of silver concentration in the Park Range target area is 1×10^{-10} to 5×10^{-9} g ml^{-1}. An additional method of detecting silver is by drop freezing. This method is described.

3. Bollay, (E.) Associates, Inc. Park range atmospheric water resources program. Phase I. Water Resources Technical Publication, Research Report no. 5. Washington, U. S. Government Printing Office, 1967. DAS M09.617 B691pa no. 5.

   On page 36 a table shows the silver content in snow crystal replicas - snow formed by nucleating supercooled water drops in a cold box - by silver iodide seeding. On page 39 a table presents the Ag background concentration in snow at six locations in target area (Steamboat Springs, Colorado, area).

4. Bourquard, A. Don. Ice nucleus concentration at the ground. American Meteorological Society, Journal of the Atmospheric Sciences, 20(5): 386-391, September 1963. DAS M(05) A512j.

Daily observations of the surface concentration of ice nuclei have been made for three summers in Missouri as a part of Project Whitetop. The observations were taken with a nucleus counter of the expansion type. Ice nucleus counts varied considerably from day to day and from hour to hour; they were greater, on the average, during periods with southerly winds and high amounts of precipitable water overhead. Scheduling of observations also permitted an analysis of possible effects of cloud seeding in the area. The seeding utilized silver-iodide smokes from aircraft at distances of 25 to 45 miles from the nucleus counter. In the average, the seeded periods showed a slightly increased nucleus count at the ground, but the increase was small when compared with natural variations in the nucleus count. An indication was found that the slight increase in count during cloud seeding may persist into the day following that upon which the cloud seeding takes place. - Author's abstract.

5. Bowen, E. G. The effect of persistence in cloud seeding experiments. Journal of Applied Meteorology, 5(2): 156-159, April 1966. DAS M(05) J86joa.

A basic assumption made in the design of most cloud seeding experiments is that each seeded period is independent of those which preceded it, i.e., that no cumulative effects are present. It now appears that this assumption is not entirely valid.

An investigation is made of the effect of persistence in a typical cloud seeding experiment and it is shown that one consequence is an apparent reduction in the result of seeding with time. There is reason to believe that this has actually occurred in many cloud seeding experiments.

A modified design of experiment is suggested which will indicate whether cumulative effects have occurred and will allow a more accurate assessment of the overall result of cloud seeding. - Author's abstract.

6. Bowen, E. G. Lessons learned from long-term cloud-seeding experiments. International Conference on Cloud Physics, Tokyo and Sapporo, May 24 - June 1, 1965, Proceedings of the International Conference on Cloud Physics. pp. 429-433. DAS M74.1 I61p.

The effect of persistence in cloud seeding test areas may take several forms. From experiments of randomized seeding on a daily basis and those by storm periods, it appears that the sensitivity of the experiment is greater if randomization is by storm periods. The persistence of silver iodide has been found in a mountainous situation by Grant. There is a possibility that the persistence is due simply to the fact that rain had recently fallen in the test area. Further investigation is needed before these factors can be accepted or rejected.

7. Cooper, Charles F. and Jolly, William C. Ecological effects of silver iodide and other weather modification agents: a review. Water Resources Research, 6(1): 88-98, February 1970. DAS P.

The silver ion is among the most toxic of heavy metal ions, particularly to microorganisms and to fish. The case with which Ag forms insoluble compounds, however, reduces its importance as an environmental contaminant. Ag is not likely to concentrate to harmful levels through either terrestrial or aquatic food chains. There is some possibility that Ag from cloud seeding will retard growth of algae, fungi, bacteria, and fish in fresh water; additional laboratory investigations are needed. Inhibition of aquatic microorganisms would interfere with the cycle that returns essential nutrients to the water. Ag in air and water should be regularly monitored. Iodine in AgI poses no environmental danger. Organic seeding agents currently being proposed are not likely to be toxic in either the short or the long run, but dispersal of proprietary organic compounds should be prohibited unless their composition is fully revealed. - Authors' abstract.

8. Cooper, Charles F. and Jolly, William C. Ecological effects of weather modification: a problem analysis. U. S. Office of Atmospheric Water Resources, Project Skywater: Atmospheric Water Resources Program; Annual report 1969. March 1970. pp. 159-171. DAS M09.617 U586pr 1969.

The purpose of this report is to evaluate the changes in the structure, organization, and behavior of natural plant and animal communities likely to result from weather modification. The text includes information on (1) specific anticipated effects of weather modification on (a) populations of plants and animals and (b) ecological change in relation to land management, (2) fog dispersal, hail and lightning suppression, and hurricane control, (3) ecological effect of seeding agents, and (4) monitoring the effects of weather modification. On page 166 one paragraph describes briefly the ecological effects of silver iodide.

9. de Pena, R. G. and Caimi, E. A. Hygroscopicity and chemical composition of silver iodide smoke used in cloud seeding experiments. American Meteorological Society, Journal of Atmospheric Sciences, 24(4): 383-386, July 1967. DAS M(05) A512j.

The aerosol produced by a commercial device used for cloud seeding experiments was studied by electron microscopy, electron diffraction, chemical analysis, and a replica method to test the hygroscopicity of the particles. The electron micrographs obtained from the aerosol when applying the replica method showed the hygroscopic nature of the aerosol particles.

We deduced from chemical analysis that the aerosol is composed of silver and potassium iodides in the ratio of approximately 2:1.

From an electron diffraction pattern and other considerations, the formation of a double salt or a solid solution is indicated; its nature should be considered in further work. - Authors' abstract.

10. Douglas, William J. Silver iodide generators and public health. American Society of Civil Engineers. Irrigation and Drainage Division, Journal, 96(3): 273-280, Sept. 1970. DAS P.

Examination of the effluent of a propane-acetone silver-iodide generator reveals its chemical contents and their concentrations at the level where an operator might encounter them present no hazard. These same materials are released to the atmosphere in quantities so small, they may be disregarded as a source of air pollution or subsequent water pollution. A silver-iodide generator and an automobile engine are similar in size and fuel consumption rate. Both release unfiltered combustion products to the free air close to the ground. Examination of automobile exhaust reveals many materials that are substantial contributors to air pollution. Two of these materials, carbon monoxide and lead halides, present potential and actual toxic hazards. The inoffensive nature of the effluent from a silver-iodide generator is emphasized by this comparison. - MGA 22.7-124.

11. Douglas, William J. Toxic properties of materials used in weather modification. National Conference on Weather Modification, April 28 - May 1, 1968, Albany, New York, 1st, Proceedings. pp. 351-360. DAS M09.6 N277pr 1968.

This study presents an explanation of toxicity ratings, definitions of terms used in discussing the toxicity ratings, countermeasures to be used when concentrations of air contaminants may be hazardous, and toxic properties of materials used in weather modification. The materials used in weather modification include silver iodide, silver compounds, soluble silver compounds versus silver iodide, iodides, and various materials used in generating silver iodide smoke.

12. Elliott, Robert D. and Thompson, John R. Persistence of nuclei in the Santa Barbara test area 1967-68 winter season. Final Report. China Lake, Calif., Naval Weapons Center, October 1968. 32 pp. (NWC TP 4646). DAS M(055) U586tp TP-4646.

Evidence has been gathered to determine whether there is a persistence effect resulting from pyrotechnic seeding. The seeding was conducted from a 3500' ridge line in Santa Barbara County into passing convection bands during the months of January through April 1968.

It was expected that such an effect, if present, would reduce the sensitivity of the statistical tests of the effectiveness of the cloud seeding in increasing precipitation since there would be a lingering effect of seeding from one seeded band to a following non-seeded band.

Special measurements of ice-forming nuclei concentrations were made by means of an NCAR-type ice nuclei counter during the latter part of the season, following the cloud seeding, at a number of sites near and downwind from the seeding site.

A two-fold analysis of the persistence effect was made. The first type was based upon a study of ice nuclei concentration decay curves following termination of seeding. The second type was based upon comparison of seeded and non-seeded band test area precipitation values at different stages of the seeding season.

Some evidence was found indicating a lingering ice nuclei effect continuing in the valley area even as long as a month following seeding. The precipitation analysis also indicated that some seeding precipitation enhancement may have occurred in non-seeded bands which followed on seeded bands. The evidence is not clear-cut as the sample size was small. - Authors' abstract.

13. Fletcher, J. E. and Millar, H. C. Atomic absorption as an index of the silver concentration in precipitation. 26 pp. Utah Water Research Laboratory, Utah State University, Logan, 1968. (Not in DAS)

14. Gabriel, K. R.; Avichai, Y.; Steinberg, Raya. A statistical investigation of persistence in the Israeli artificial rainfall stimulation experiment. Journal of Applied Meteorology, 6(2): 323-325, April 1967. DAS M(05) J86joa.

A number of tests of the data of the Israeli rainfall stimulation experiment have not shown any evidence of persistence of effects of cloud seeding, either from day to day, or within each season, or from season to season. - Authors' abstract.

15. Grant, Lewis O. Indications of residual effects from silver iodide released into the atmosphere. Western Snow Conference, Yosemite National Park, California, April 17-19, 1963, Proceedings. pp. 109-115. DAS M(06) W527p.

An inspection of the Climax, Berthoud Pass and Mount Washington ice nuclei data shows that ice nuclei concentrations on non-seeded days during seeded intervals have been substantially higher than those during non-seeded intervals. This suggests a carry over or residual effect from seeding with silver iodide. The uncertainties in many of the characteristics of ice nuclei, the inadequacies of procedures for observing them, limited information on natural and artificial nuclei sources, and lack of understanding of a process by which a carry over effect might work, precludes a final assessment of its reality at this time. Investigations in progress are expected to provide an improved understanding of the indicated residual effect. A residual effect of the nature suggested above would have considerable bearing on the design of weather modification experiments, especially if randomization is to be employed, and on the planning, operation, and analysis of commercial seeding efforts. - Author's conclusions.

16. Hogan, A. W.; Robertson, C.; Edwards, C. P. Application of an inert tracer to an AgI seeding experiment. Journal of Applied Meteorology, 8(1): 169-171, February 1969. DAS M(05) J86joa.

In this note a description of a cloud seeding experiment conducted in the Park Range on February 3, 1968, is included. The silver content of the snow which fell between 1615 and 1645 was 6.0×10^{-9} gm ml^{-1} (background less than 0.2×10^{-9} gm ml^{-1}) as determined by an atomic absorption spectrophotometer.

17. Isono, Kenji. Some result of cloud seeding experiments with use of silver iodide ground generators. International Geodetic and Geophysical Union, Monograph no. 16: International Conference on Cloud Physics, Australia, September 1961. pp. 75-76. Paris, January 1962. DAS M(055) I61mo no. 16. (Only abstract available in DAS)

Two series of randomized cloud seeding experiments using kerosene silver iodide smoke ground generators were made in the Okutama and the Gumma regions in Japan. The periods of seeding or not-seeding were assigned on the basis of a set of random numbers. Samples of rainwater were collected at stations in the target areas and the concentration of silver iodide, chloride and fluorescent material were determined.

The result of a statistical analysis of the ratios of total amount of precipitation at each station in the seeded periods to that in the unseeded periods shows that the increase of precipitation in the target area was significant at the level of 0.005 in the case of Okutama experiment in winter (from January to March) of 1960. The averaged ratio of the precipitation amount in the target area was 148% and there was an area in the target area where this ratio exceeds 300%. With the intention of displacing the area of maximum increase in precipitation amount about twenty kilometers to the south, the site of seeding was displaced about twenty kilometers to the south in the experiment in 1961.

The results obtained are summarized as follows:

(1) A statistically significant increase of precipitation was found in the experiments made in both regions in the period from January to March.

(2) The increase in precipitation amount in seeded periods relative to not-seeded periods was larger when precipitations were brought by warmer moist clouds in winter.

(3) The concentration of seeded silver iodide in rain (or snow) water collected in the target areas was high in areas where precipitation was large. The areas of maximum silver iodide concentration in rain water appeared not in the area near to the seeding site where silver iodide concentration in the air was highest, but in the area at some distance from the seeding site (about 50km in the case for Gumma region). These facts rule out the idea that silver iodide detected in rainwater resulted from the capture of silver iodide particles by falling raindrops.

(4) The distance from the generators to the areas of maximum increase in precipitation amount increased with increasing height of the freezing level above the ground.

(5) The area of maximum increase in precipitation in the Okutama region in 1961 moved to the south relative to that in 1960 in accordance with the displacement of the seeding site.

(6) Observation of the shapes of fallen snow crystals reveals that needles occurred more frequently on seeded days than on unseeded days. - Author's abstract.

18. Kahan, Archie M. Weather modification effects on man's environment. Western Resources Conference, 9th, University of Colorado, 1967, Man and the Quality of His Environment: Western Resources Papers. Boulder, University of Colorado Press, 1968. pp. 81-89. DAS 301.3 W527ma.

Explores some of the effects of intentional weather modification on the human environment. A definition of weather modification is also provided. Data are presented comparing silver concentrations in treated air and in the precipitation following cloud seeding, with acceptable levels. These concentrations are of several orders of magnitude lower than maximum tolerance levels for both air and water. Relative concentrations of other seeding materials are also considered. Fog dispersal techniques employed near Orly Airport, France, produced light snow but icy road warning signs effectively reduced accidents. It is contended that careful monitoring of seeding activities reduces, rather than increases, flood hazards. Evidence suggests that no significant downwind decrease in precipitation is likely; on the contrary, an increase may be anticipated. It is believed that operations for lightning suppression in areas susceptible to forest fires will have little effect on precipitation; high suppression activities, however, may actually increase precipitation. Results of hail suppression efforts are inconclusive. Progress in moisture management can result only from much careful study and experimentation. - MGA 20.12-161.

19. Koenig, L. Randall. Some chemical and physical properties of silver-iodide smokes. Journal of Applied Meteorology, 3(3): 307-310, June 1964. DAS M(05) J86joa.

The aerosols, produced by several devices, used to provide silver iodide for cloud-seeding purposes have been studied by micro-chemical techniques which permitted the characterization of individual smoke particles. The water sorptive properties, the composition, and chemical uniformity of the particles were sought. Marked differences in the generator outputs were noted. Some effort has been made to relate the findings of this work to the suitability of the different aerosols to cloud-seeding tasks. - Author's abstract.

20. Morgan, G. M., Jr. and Rosinski, J. A field technique for detecting silver iodide in snow. Journal of Applied Meteorology, 6(4): 656-661, August 1967. DAS M(05) J86joa.

A field technique was developed to detect silver iodide seeding agent in snow samples. The technique consists of collecting snow during a snow storm, forming liquid drops by melting pellets made from the snow, and refreezing the drops. A histogram of frequency of drop freezing plotted against temperature indicates the presence or absence of silver iodide in snow. - Authors' abstract.

21. Mossop, S. C. and Tuck-Lee, C. The composition and size distribution of aerosols produced by burning solutions of AgI and NaI in acetone. Journal of Applied Meteorology, 7(2): 234-240, April 1968. DAS M(05) J86joa.

The Warren-Nesbitt generator is widely used in Australia and other countries for producing a cloud seeding aerosol by burning a solution of silver iodide and sodium iodide in acetone. It is found that the particle size distribution follows a log probability law with median diameter 0.085 μ and standard deviation factor 1.47. Electron diffraction examination of the particles shows that they consist of beta silver iodide and sodium iodide. The available evidence indicates that each particle is probably a mixture of these two constituents. - Authors' abstract.

22. Neutron activation analysis of silver content in precipitation samples. E. Bollay Associates, Inc., Final Report, Contract No. 14-06-D-5573, Boulder, Colorado, December 1, 1965. (Not in DAS).

23. Nevada. University. Desert Research Institute. Laboratory of Atmospheric Physics. Final report on Skywater. Bureau of Reclamation Contract No. 14-06-D5995-1966. (In: U. S. Office of Atmospheric Water Resources. Project Skywater: Atmospheric Water Resources Program; Annual Report 1968. Contractor Reports. pp. 99-120) DAS M09.617 U586pr 1968.

On pages 114-119 analyses of precipitation for trace amounts of seeding materials in the Elko region are studied. The results of the analyses of silver concentration in snow samples in Reno - Mt. Rose area, Elko Project, and the Coop I Experiment (Colorado) are presented in tabular form. Analysis methods are compared.

24. North American Weather Consultants, Goleta, California. Performance of an Atmospheric Water Resources Research Program in the Hungry Horse area, Montana, 1967-68 season. Interim Report. Bureau of Reclamation Contract No. 14-06-D-6039. (In: U. S. Office of Atmospheric Water Resources. Project Skywater: Atmospheric Water Resources Program; Annual Report 1968. Contractor Reports. pp. 335-346) DAS M09.617 U586pr 1968.

On pages 339-341 there is a discussion on the silver content of the snow in the Hungry Horse area of Montana for evaluation of seeding (AgI) effectiveness. From samples collected in mid-January, March, and April the analysis shows concentrations lower than the lowest ranked sample in 1966-1967 season. The background concentration is approximately an order of magnitude less than the previous year. There is a possibility that background concentrations vary from year to year. Another hypothesis is that the collection and/or analytical procedures were changed from one year to the next.

25. North American Weather Consultants, Goleta, Calif. Performance of an Atmospheric Water Resources Research Program in the Hungry Horse area, Montana, 1967-68 season. Second Interim Final Report. Report No. 97. 46 pp. DAS M(051) N864re no. 97.

An attempt to more accurately delineate the area of seeding effect includes the collection of snow samples in and around the target area of Hungry Horse area, Montana, for silver analysis. The 35 samples were collected in mid-January, March, and April. Results are presented in a table in rank order form.

Silver concentrations for 1968 data range from a high of 1.98×10^{-10} gm/ml. to a low of 6.50×10^{-12} gm/ml. The range of the previous year was from 2.0×10^{-8} to 2.08×10^{-11} gm/ml. Background concentrations seem to vary from year to year, making inter-year comparative analysis difficult. Only the 1968 data are examined on pages 17-26.

26. Parungo, Farn P. and Rhea, J. Owen. Field use of a simple technique for identifying silver iodide particles as snow crystal nuclei. Journal of Applied Meteorology, 9(4): 651-656, August 1970. DAS M(05) J86joa.

A procedure is presented for identifying those silver iodide particles in ice crystals that have behaved as snow crystal nuclei. The new technique is based on the principle that any submicron particle can act as a nucleus in its own supersaturated solution, and can grow to any desired crystal size (the final size depending on time of exposure to the supersaturated solution). For the procedure presented here, an aqueous solution of 30% potassium iodide supersaturated with silver iodide is used.

Application of the technique in a weather modification field research project is described. A case-study example is presented, and results of the season's experiments are discussed with emphasis on contributions of the nuclei identification data. It is concluded that the technique has considerable practical utility in qualitative determination of effects from cloud seeding. - Authors' abstract.

27. Parungo, Farn P. and Robertson, Charles E. Silver analysis of seeded snow by atomic absorption spectrophotometry. Journal of Applied Meteorology, 8(3): 315-321, June 1969. DAS M(05) J86joa.

An experimental weather modification program using silver iodide as the cloud seeding agent is being conducted over the Park Range in northwestern Colorado. The measure of silver content in target area precipitation can be used as an aid in tracking the silver iodide plume and evaluating seeding results.

The ultramicroquantities of silver in snow samples are concentrated by a solvent-extraction technique with an organic complexing reagent, and silver content is then determined by atomic absorption spectrophotometry. This analytical method is capable of detecting silver iodide activities in seeded snow. The results obtained using this technique on Park Range target area snow samples are discussed. - Authors' abstract.

28. Rosinski, J. and Parungo, F. Terpene-Iodine compounds as ice nuclei. Journal of Applied Meteorology, 5(1): 119-123, February 1966. DAS M(05) J86joa.

Silver iodide particles deposited on vegetation may photolyse and combine with natural terpenes from tree oils to form compounds which either themselves become aerosols, or become attached to aerosol particles. In either case the new compounds may become active centers acting as freezing nuclei. Silver iodide particles may persist for several months when deposited on coniferous trees, and may release variable doses of such freezing nuclei during that time. Although the concentrations of ice nuclei so produced are probably too small to influence precipitation, they may nevertheless contaminate large areas and thus may be significant for long-range research programs concerned with measuring natural concentrations of freezing nuclei. - Authors' abstract.

29. Sax, N. Irving. Dangerous properties of industrial materials. Third edition. New York, Van Nostrand Reinhold Company, 1968. 1251 pp. DAS 614.83 S272dan.

This reference contains general information, hazard analysis and countermeasures for silver iodide; toxicity of silver compounds; toxic hazard rating, toxicology, disaster hazards, and countermeasures of iodides; general information and hazard analysis of various chemicals, as potassium iodide and sodium iodide found in the chemical composition of AgI smoke.

30. Schaefer, Vincent J. and Fuquay, James J. The detection of silver iodide in snow by neutron activation analysis. Journal de Recherches Atmosphériques, Vol. II, April-June 1965, no. 2, pp. 49-52. DAS M(05) J86jor 2:1965.

Laboratory and field samples of ice crystals grown on submicroscopic silver iodide aerosol particles have been collected and subjected to neutron activation analysis. The residue has been found to contain a concentration of silver more than an order of magnitude greater than samples from an area in the Colorado Rockies where silver iodide seeding has not occurred. This analysis technique may constitute a new approach to the physical evaluation of cloud seeding effects. - Authors' abstract.

31. Shaffer, Russell W.; Brown, Keith J.; Elliott, Robert D. Performance of an Atmospheric Water Resources Program in the Hungry Horse area, Montana, 1966-67 season. North American Weather Consultants, Goleta, Calif., Interim Final Report, Report No. 15-9. October 15, 1967. 100 pp. DAS M(051) N864re 15-9.

On pages 33-42 an analysis is presented of the silver concentration in the snow in the Hungry Horse area during the cloud seeding project of 1966-67 season based on a series of snow samples collected during the period February 6 to April 14, 1967. Tables contain the raw data received from the analyzer, Desert Research Institute of University of Nevada, and the complete rank order data. The silver concentrations ranged in value over four orders of magnitude (max 2.0×10^{-8}; min 2.08×10^{-11}). The neutron activation techniques as reported by Warburton and Young (1967) were applied to determine the silver content.

32. Summers, Peter W. and Renick, James H. Case studies of the physical effects of seeding hailstorms in Alberta. American Meteorological Society, Bulletin, 52(7): 636, July 1971. (Paper presented at the International Conference on Weather Modification, September 6-11, 1971, Canberra, Australia) DAS

M(05) A512b. (Only abstract available in DAS)

During Project Hailstop 1970, several cloud seeding experiments were carried out using an airborne droppable pyrotechnic flare system. The experimental design emphasizes physical rather than statistical evaluation. No fixed target area is defined and the seeding is not randomized. A severe storm is selected for seeding and then monitored closely by the various observing techniques developed by the Alberta Hail Studies Project. Because of the precision of this seeding system, events can be related to a known space and time origin. An attempt is made to detect reproducible physical changes caused by the seeding that are consistent with the current theory of Alberta hailstorms.

The results obtained from two well documented seeded hailstorms on 9 July and 11 July 1970 are presented. Newly developing cloud towers on the southern flank of the storms were heavily seeded during a five- to ten-minute period at rates equivalent to 5000 gm of AgI per hour. The tower growth was observed by time-lapse photography and then subsequently as a radar cell moving through the storm complex. Time versus height profiles of maximum radar reflectivity in the cells were constructed and the seeded cells compared to the unseeded cells. Some differences between the radar characteristics of seeded and unseeded cells were noted, and one interpretation is that of smaller hailstones falling from the seeded cells.

The extreme variability of the hail pattern on the ground makes evaluation difficult. No serious damage was reported from the seeded cells although the same is true of some unseeded cells; however, several unseeded cells did produce moderate to severe damage.

Precipitation samples were analyzed for freezing nuclei spectra using the technique of droplet freezing on a cold stage. The samples were also analyzed for silver content using atomic absorption spectrophotometry. More nuclei active at warmer than usual temperatures and silver concentrations of the order of one to four parts per billion were found in the samples collected downwind of the seeding. The earliest time after seeding at which silver was detected in precipitation at the ground was 12 min about 10 km downwind. The silver iodide was well diffused through the storm system and was detected up to two hours after seeding, 65 km downwind.

Some preliminary results of the 1971 experiments will also be presented and discussed. - Authors' abstract.

33. Super, Arlin B.; Yaw, Robert H.; Sandoval, Angelito R. Atmospheric water resources program. Final Report Contract No. 14-06-D-6144. Bozeman, Montana State University, Dept. of Earth Sciences, 1969. 59 pp. DAS M(051) S959atm.

Results of Neutron Activation Analysis of snow samples taken (1) April 11-15, 1969, after termination of seeding operation, (2) April 22-30, 1968, before any cloud seeding, and (3) on February 6 during seeding operations of the Bangtail Mountain area are presented. Silver concentrations of April 1969 are generally within the range suggested by E. Bollay Associates as typical of seeded areas (2×10^{-11} to 2×10^{-10} gm Ag/ml).

34. Vali, G. Ice nucleation. Maybank, J. and Baier, W., Weather modification: a survey of the present status with respect to agriculture. pp. 69-80. Ottawa, Ontario, Canada Committee on Agrometeorology, January 1970. DAS M09.617 M467we.

On pages 72-75 the author presents details of generation techniques of silver iodide. Some properties of silver iodide are that it is practically insoluble in water and it is hydrophobic. Both of these properties can be affected by bulk and adsorbed impurities. AgI is subject to photo-decomposition. The generation of silver iodide smokes is usually from solutions which include complexing agents such as potassium iodide and sodium iodide. The smoke particles are not of pure AgI but contain various amounts of soluble components.

35. Warburton, Jack A. and Young, L. G. Evidence of persistence or cross-contamination in cloud seeding experiments. Western Snow Conference, Lake Tahoe, Nevada, April 16-18, 1968, Proceedings. DAS M(06) W527p 36: 1968.

One hundred and fifty samples collected during 1966-67 have been analyzed for silver content using thermal neutron activation methods. The samples were collected in five separate regions of the western United States. In two of the locations where extensive randomized silver iodide seeding was occurring, with seeding periods of one day, there is evidence of persistence of silver in the atmosphere in unseeded situations. Silver, in relatively high concentrations, was present in specific storms which yielded precipitation in an unseeded region, It is speculated that this silver originated in cloud-seeding regions upwind of this unseeded area. Results also provide evidence that silver iodide released from the ground in one mountainous seeding area is not arriving in the target area precipitation. This is in strong contrast to results in two other similar seeding projects where high concentrations of silver are observed. - Authors' abstract.

36. Warburton, J. A. The detection of silver in hail, rain and snow by neutron activation analysis. American Meteorological Society, Bulletin, 48(1): 27, January 1967. (Paper presented at the Conference of the American Meteorological Society on Physical Processes in the Lower Atmosphere, March 20-22, 1967, Ann Arbor, Michigan.) DAS M(05) A512b. (Only abstract available in DAS)

A new technique has been developed for the rapid and efficient handling of precipitation samples collected from cloud seeding experiments. Operational methods have been developed to handle many samples quickly and relatively cheaply. The method is one in which other metallic contaminants are removed from samples prior to analysis. The detection limits are low and are determined by the available instrumentation. Results of analysis of precipitation samples will be presented together with details of the techniques used. - Author's abstract.

37. Warburton, J. A. and Maher, C. T. The detection of silver in rainwater: analysis of precipitation collected from cloud-seeding experiments. Journal of Applied Meteorology, 4(5): 560-564, October 1965. DAS M(05) J86joa.

Measurements were made of the concentration of silver in precipitation samples collected in areas of Australia where cloud seeding with silver iodide has occurred. Silver was detected in 41 of 63 'seeded' samples and in three of 23 'unseeded' ones. Values of concentration of the silver were between 3×10^{-12} gm ml^{-1} and 4.8×10^{-11} gm ml^{-1}. There is some evidence that silver is detected more frequently when the precipitation falls from seeded clouds which have top temperatures $< -15C$. - Authors' abstract.

38. Warburton, J. A. The detection of silver in rainwater: Further developments of technique. Journal of Applied Meteorology, 4(5): 565-568, October 1965. DAS M(05) J86joa.

Details are presented of the experimental processes involved in the concentration of silver ions from water. Monitoring procedures which lead to improvements in reliability in the techniques are described. The performance of the detection system using better quality ion-exchange resins, has been measured using the radio-isotopes Ag^{110} and Ba^{131} in dilute aqueous solutions. The lower limit of detection has been extended to ion-exchange column loadings of 4×10^{-8} gram of silver. - Author's abstract.

39. Warburton, J. A. The detection of silver in rain water from cloud seeding experiments in Australia. Journal of Applied Meteorology, 2(5): 569-573, October 1963. DAS M(05) J86joa.

A technique is being developed for detecting silver in very low concentrations in water. It is effective down to concentrations of 5×10^{-12} gm ml^{-1}.

The method involves collecting and concentrating the silver ions on an ion-exchange column, precipitating the silver collected as AgI and measuring its quantity by a cold-chamber method.

The performance of the system has been measured using the radio-isotope Ag^{110} in the form of aqueous solutions of $AgNO_3$. The column collects over 90 per cent of the silver ions from samples with concentration greater than 10^{-11} gm ml^{-1}. For column loadings down to 10^{-7} gram, the elution efficiency, using a strong cation (Ba^{++}) as the eluting substance, is greater than 20 per cent.

When the technique was used on samples of rainwater in the field, no silver was detected except when the rain fell from clouds which had been seeded with AgI. - Author's abstract.

40. Warburton, J. A. and Young, L. G. Neutron activation measurements of silver in precipitation from locations in western North America. Journal of Applied Meteorology, 7(3): 444-448, June 1968. DAS M(05) J86joa.

Thermal neutron activation methods have been applied to the determination of silver content in samples of hail, rain and snow. Hail and rain samples were collected in South Dakota in regions where AgI cloud seeding was being conducted; the snow was collected in the eastern Sierra Nevada in an area where no such seeding was being conducted. No silver was detected in the snow samples analyzed, indicating concentrations on the average less than 2.5×10^{-11} gm ml^{-1}. Eighty percent of the hail and rain samples analyzed contained measurable quantities of silver up to 70 times the minimum detectable amount. Some of these latter samples were collected in nominally unseeded areas, and although the chemical form in which the silver entered the precipitation is unknown--thereby casting doubt on its consequence--the observations raise important questions which deserve answers, particularly as they may affect statistical evaluations of weather modification experiments. - Authors' abstract.

41. Warburton, J. A. and Young, L. G. Neutron activation procedures for silver analysis in precipitation. Journal of Applied Meteorology, 7(3): 433-443, June 1968. DAS M(05) J86joa.

Laboratory techniques have been developed for concentrating and isolating silver from aqueous samples. When these concentrated samples are activated in a thermal neutron flux of 4×10^{12} n cm^{-2} sec^{-1}, quantitative measurements down to 10^{-9} gm masses of silver can be made. When 1-liter samples of water are used, the lower limit of detection of silver in the sample is about 3×10^{-12} cm^{-3} concentration. Typical Ag concentrations being observed in snow collected in the western United States range from this lower limit to 10^{-8} gm cm^{-3}, the majority being between 10^{-9} and 10^{-11}. The lower limit does not therefore appear to be a serious factor in silver determinations in snow collected at ground stations. The system described is a nondestructive one, the accuracy of measurement using γ-ray spectrometry being 1, 2, 10 and 80% for masses of silver 10^{-6}, 10^{-7}, 10^{-8} and 10^{-9} gm, respectively. By using a 24-sec half-life radioisotope for the Ag determination, the cost of activation and turn-around time on samples is kept to a minimum. Data analysis is computerized and rapid. - Authors' abstract.

42. Warburton, Joseph A. Trace silver detection in precipitation by atomic absorption spectrophotometry. Journal of Applied Meteorology, 8(3): 464-466, June 1969. DAS M(05) J86joa.

Using silver iodide seeded snow which fell in the Old Faithful area of Yellowstone National Park several measurements of the concentration of silver were made in one half of the sample by using the atomic absorption spectrophotometer. The mean concentration of silver was calculated to be 1.1×10^{-8} gm ml^{-1}.

Neutron activation analysis was used to determine the silver content in the other half of the sample. By this method the average concentration of silver in the snow was 1.3×10^{-8} gm ml^{-1}.

43. Washington. State. Bureau of Reclamation summary. (In: U. S. Office of Atmospheric Water Resources. Project Skywater: Atmospheric Water Resources Program; Annual Report 1970. Summary and Contractor Reports. pp. 349-358) DAS M09.617 U586pr 1970.

On page 353 the analysis of silver content in snow by atomic absorption spectrophotometer from samples of snow collected at Keechelus Dam, Snoqualmie Pass, Stampede Pass, and the mobile laboratory is discussed briefly. In no case was the concentration of silver greater than 1×10^{-10} gram per ml of water. Measured concentrations of silver in three samples of ice collected from the leading edge of aircraft after it had flown through clouds over the Cascades show concentrations similar to those in the snowfall at ground level.

44. Yang, I. K. A preliminary survey for the seeding experiment in Korea. International Conference on Cloud Physics, Tokyo and Sapporo, May 24 - June 1, 1965, Proceedings of the International Conference on Cloud Physics. pp. 434-437. DAS M74.1 I61p.

Some rainwater samples were collected for the purpose of detecting silver iodide in seeded rainwater in the Seoul area after several cloud seeding flights on January 28, 1964. Warburton's method was used for the analysis. Practically no AgI was detected in the rainwater.

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