RESEARCH PROGRAM PRESENTATION

ATMOSPHERIC MECHANISMS EFFECTIVE IN SCAVENGING LEAD AEROSOLS

Objective

The objective of this research program is to describe in quantitative terms the mechanisms which are important in the removal of lead aerosols from the atmosphere, to provide estimates of their effectiveness, and to relate these removal mechanisms to urban lead aerosol emissions.

Discussion

It is obvious that the atmosphere has various natural mechanisms which act to cleanse it of impurities, both particulate and gaseous. If this were not so, conditions long ago would have passed beyond tolerable levels on a world-wide scale. The various physical mechanisms active in the atmosphere for removing particulate materials include: (1) settling or fallout, (2) rain-out through condensation processes, (3) washout by droplet scrubbing action, and (4) impaction on solid surfaces. These various mechanisms have been carefully studied in the past for various materials and especially with reference to nuclear fallout from weapons tests. To apply these principles to lead aerosols will require first a consideration of realistic aerosol and atmospheric environmental factors. Then calculations can be made of the behavior of the lead aerosol for chosen atmospheric and topographic conditions. From these calculations some realistic estimates can be made of the effectiveness of the atmospheric removal mechanisms for lead aerosols.

Research on atmospheric scavenging mechanisms directly related to lead aerosols can now be undertaken with some degree of confidence in the applicability and usefulness of the result to urban areas because of the knowledge obtained in previous research by the Institute on the size distributions of the urban lead aerosol.

It also seems quite likely that this research program would be an informative program, complementary to the vegetation deposition studies being done by E.A. Schuck at the University of California, Riverside.

Previous research work by Stanford Research Institute has indicated that the urban atmospheric lead aerosol has a size distribution which does not change markedly over a wide range of locations. A representative size distribution has been shown to have 25% of the mass smaller than 0.16 equivalent diameter, 50% less than 0.25 , and 25% larger than 0.45 . This size distribution appears to be generally applicable to a number of California, midwestern, and eastern U.S. urban areas. It therefore seems unnecessary at this time to cover a wide range of particulate size distributions in any experimental program dealing with urban removal processes. However, at some future time the nature of lead particulates in more remote areas may require consideration of a broader range of size distributions.

As mentioned before, settling is one of the mechanisms which should be considered when studying the processes by which lead leaves the atmosphere. If the settling were solely controlled by gravitational and viscous effects we would expect that particles would pass to the ground at the Stokes-

Cunningham settling velocity, which for a 0.25 particle is about 0.001 cm/sec. This very small settling velocity is often ignored in diffusion estimates of atmospheric concentration because whether or not it is included makes little difference in the final calculation. However, there is considerable evidence that the Stokes-Cunningham velocity is not the factor which should be used to estimate the deposition of submicron particles from the atmosphere. A.C. Chamberlain[1] has defined and measured what he calls a velocity of deposition; atmospheric diffusion formulas have been derived to incorporate this factor. From these formulas, downwind deposition and concentration amounts for moderate downwind ranges can be calculated based on source conditions, aerosol characteristics, and the nature of the surface.

Chamberlain's velocity of deposition cannot be calculated but must be determined experimentally for different surfaces. Chamberlain has measured the deposition velocity of uranium fume, 0.2 diameter, onto grass and obtained a value of about 0.2 cm/sec. This is larger than the calculated terminal velocity by atleast 2 orders of magnitude and would be an important factor to be included in estimates of atmospheric deposition of this material. Deposition rates were also dependent on the nature of the surface, i.e., a grass surface had a different deposition rate than a flat filter paper. This type of behavior may also be true of lead aerosols in this general size range.

Aerosols are also modified and scavenged from the atmosphere by coagulation, rainout, and washout processes. These processes have been shown to be important factors in determining the atmospheric cycles of other aerosols such as sulfates and nuclear debris, and it is expected that these processes can be shown to be effective in modifying and removing urban lead aerosols from the atmosphere.

Method of Approach

This research program will be broken down into two general topics: (1) experimental determination of the dry deposition characteristics of lead aerosols over the size ranges found in the atmosphere, and (2) calculation of the theoretical efficiency with which lead aerosols are removed or scavenged from the atmosphere by other natural mechanisms.

The first phase of the proposed research would be directed toward experimental determination of the velocity of deposition of urban aerosols.

The experimental program to determine the velocity of deposition of urban lead aerosols will be centered around a simple wind tunnel. The lead aerosol content of this natural atmosphere in Menlo Park will be used as the source aerosol. This is considered to be preferable to setting up a special generation system. Since our available data on urban lead aerosols indicate a generally consistent size distribution, data obtained on local aerosol characteristics should be generally applicable to other urban areas.

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[1] Chamberlain, A.C., Transport of particles across boundary layers, AERE-M 1122. Atomic Energy Research Establishment, Harwell, England (1962).

The wind tunnel exposure chamber will be a simple square wooden duct about 30 inches on a side, located on the roof of one of the present buildings. This will protect the experiment from direct exposure to very local dust and exhaust sources. The air intake will not be filtered, but will contain a flow alignment section to restrict the degree of turbulence in the flow through the chamber.

The working section of the chamber will permit various typical surfaces to be exposed to the aerosol stream under constant known air flow conditions. After a period of exposure the surfaces will be analyzed for deposited lead. Measurements will also be taken of the total lead concentrations and particle size distribution. From these data the velocity of deposition will be calculated using Chamberlain's expression:

$$D = (V_d)\,(C)$$

where: V_d is velocity of deposition
D is deposition rate per unit area
C is volume concentration

The surfaces to be studied will include smooth Millipore filter material, grass, leaf type vegetation, rough pavement, and water. The grass, vegetation, and pavement may have to be simulated from low-lead materials in order to be able to detect the deposited lead above a natural background. All of the experiments will be replicated a number of times.

In the second phase of this research program the other mechanisms by which lead can be removed from the atmosphere would be studied theoretically. Our present knowledge of the characteristics of urban lead aerosols should allow the application of existing theories of coagulation, washout, and rainout processes. The difference in these latter two processes is that in washout the particles become attached to the precipitation during the falling process; whereas particles removed by rainout have become part of the droplets prior to the actual precipitation.

There have been a number of studies of washout processes. For example, Chamberlain[2] has used Langmuir's[3] calculations of efficiency of impaction and Best's[4] raindrop size distributions to determine the rate of scavenging of monodisperse aerosols. Greenfield[5] has also studied the problem and Pemberton[6] has considered the special case of non-wettable particles. The above cited studies and others of the same type would serve as a basis for estimating the effects of washout on the removal of lead particulates from the atmosphere.

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2 Chamberlain, A.C., Aspects of travel and deposition of aerosol and vapor clouds, Atomic Energy Research Establishment, Harwell, AERE HP/R 1261, Harwell, England (1953).

3 Langmuir, I., The production of rain by a chain reaction in cumulus clouds at temperatures above freezing, J. Meteorol. 5, 175-92 (1948).

4 Best, A.C., The size distribution of raindrops, Quart. J.Roy. Meteorol. Soc. 76, 16-36 (1950).

5 Greenfield, S.M., Rain scavenging of radioactive particulate matter from the atmosphere, J. Meteorol. 14, 115-25 (1957).

6 Pemberton, C.S., Scavenging action of rain on non-wettable particulate matter suspended in the atmosphere, Itern. J. Air Pollution, 3, 168-78 (1960)

Theoretical and experimental studies of rainout have been made. Several of these are described by Junge [7] in his book and it appears that such studies could be applied to the particular problem of lead compounds. Coagulation and other possible mechanisms of aerosol modification and removal would also be considered.

In addition to the survey of the literature relating to theory and experiments on aerosol modification and removal and the application of these works to atmospheric lead aerosols, it would be worthwhile checking calculations against observations where possible. Dustfall studies have been made and some of these have measured lead compounds (e.g., Johnson and Rossano's study in Seattle [8]). Attempts would be made in the program to check calculations with any observations which are available in the literature, but no experimental measurement program is planned for this phase of research.

In the final report which would be prepared at the conclusion of this program the results of the research would be related to the atmospheric dispersal of urban lead aerosols.

COST ESTIMATE

This research would probably require about one year to complete.

An approximate estimate of the costs of this research has been made. This estimate indicates that the cost of this research would be approximately $35,000.

This research could be begun early in 1967.

Elmer Robinson, Senior Meteorologist
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7 Junge, C.E., Air Chemistry and Radioactivity, Academic Press, New York pp. 291-93 (1963).

8 Johnson, R.E. and A.T. Rossano, Extended chemical analysis of dustfall, paper presented at the Seventh Conference on Methods in Air Pollution Studies, Los Angeles, Jan. 25-26, 1965. Sponsored by California State Department of Public Health.