STUDY OF RAINOUT OF RADIOACTIVITY IN ILLINOIS

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by

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The field experiments have been continued to estimate convective storm particulate scavenging efficiency in proximity to the St. Louis, Missouri urban-industrial complex. Complimentary studies of the urban aerosol characterization, source strength, and removal processes were also studied.

The 1974 field effort produced the following types of samples for analysis and interpretation: 1) 1440 total rain samples from 80 sites; 2) 150 sequential rainwater samples from 3 locations; 3) 73 wet/dry samples from 8 sites; 4) 146 air filter samples from 8 locations; and 5) 27 air filter samples from aircraft. The analysis procedures require that all water samples undergo filtering for separate analyses of soluble and insoluble fractions of the elemental concentrations. This data collection effort provided 3672 samples for chemical analysis. The status of the analysis of all types of data is described.
ACKNOWLEDGMENTS

The successful operation of a field project of this magnitude requires the full cooperation of every individual involved. This has certainly been true of METROMEX from the outset and was more than true in 1974 when many people were asked to go beyond the normal routine of activities and perform added tasks. To all of our METROMEX colleagues, we extend a heartfelt thanks for enduring the hardships placed upon you by us in our pursuit of the scavenging studies and tracer experiments.

We gratefully acknowledge the assistance of Prof. Roscoe Braham, University of Chicago, for obtaining in-flight air samples for our aerosol studies.

This research could not be accomplished without the total dedication of Anthony Rattonetti, Mark Peden and their associates in the Chemistry Laboratory. This group of men and women have worked beyond expectations in performing seemingly impossible tasks. Without this sort of effort, the analysis would be hopelessly behind.
INTRODUCTION

The field efforts on this contract have been directed toward the use of tracer chemicals to study the scavenging processes in convective thunderstorms for the past 4 years. The effort was moved in 1971 from the central Illinois area (Project ITREX) to the major field project, METROMEX, in the St. Louis, Missouri area. This project was described in great detail in the Eleventh Progress Report. The METROMEX program was envisioned as a 5-year data collection project followed by an additional period of time to analyze and catalog the data relating to the inadvertent modification of precipitation by urban influences. The Survey AEC effort has been a vital part of this project of national importance.

The past 4 years of data collection have been very fruitful, and some preliminary results have been brought together in 2 major publications; the Eleventh Progress Report under this contract, and the report C00-1199-34 listed in Appendix B of this report. Additional papers have been published and the results of specific research topics have been presented at various scientific meetings (see Appendix A).

Although minor alterations have occurred in the field operations as dictated by the preliminary findings, the results obtained to date have not caused major changes in the emphasis of the research project. An extensive data base of surface and upper-air measurements has been acquired and will necessitate a period of time after the termination of the field effort to
interpret the observations. Further efforts of analysis will be required to present the results in a form useful for the prediction and assessment of the impact of our growing urban centers on the frequency, amount, and quality of precipitation.

Since the Eleventh and Twelfth Progress Reports contained a comprehensive description of the types of data gathered under the auspices of this contract, and also listed the quantity of observations as well as a status report of the analysis phase at that time, this report will deal with the effort expended during FY-75 in the field and in analysis.

FIELD DATA COLLECTION

A summary of the Water Survey field activities in METROMEX for 1974 is presented in report C00-1199-47 entitled "1974 Operational Report for METROMEX". The following paragraphs will amplify the portions of the data collection effort pertinent to the scavenging research.

AIRCRAFT

The aircraft used for the tracer release flights was flown on 33 occasions during 1974 and logged a total 82.6 hours of flight time. During the 6 week period of flight operations, 2 tracer missions were conducted. The remaining 31 flights were composed of second priority sampling missions or aborted attempts to release tracers.

The alternate flights for the aircraft were carried out to provide data on the structure of the atmosphere prior to and during the development of convective activity which is essential to the complete understanding of storm development and structure.
The instrumentation installed, maintained, and operated under funds from this contract during 1974 within the primary METROMEX research circle (Semonin and Gatz, 1974) included: 1) 80 total rainwater samplers; 2) 4 raindrop spectrometers; 3) 8 wet/dry samplers; 4) 3 sequential rain samplers; 5) 8 air filter samplers; 6) 3 rawinsondes; and 7) 1 TPS-10 radar. The total rainwater collection network was operated on a nearly continuous basis during the period 8 July through 17 August with changes of samplers occurring each 24 hours. The operation of the network produced rain samples on 21 days and dry samples on 1 day. Included in the samples were tracer experiments on 2 and 11 August. Since the collected samples, in general, are filtered to separate insoluble and soluble materials, the experiments produced a total of more than 2,800 samples for chemical determinations.

A total of 4 raindrop spectrometer sites were instrumented during the period 15 July through 19 August 1974. Some of these instruments were utilized as a rain-switch for the wet/dry samplers to activate the mechanism exposing a sampler to the rain while closing the side exposed to dry fallout. These raindrop spectrometer data are used to assess the scavenging efficiency of individual storm case studies. The distinct difference between the average rural drop-size distribution and the down-city distributions is striking (Semonin and Changnon, 1974) and must be evaluated for its contribution to the total downwind scavenging efficiency of modified storm events.

The network of 8 wet/dry samplers, 3 sequential rain samplers, and 8 surface air filter samplers was operated to collect data required for the determination of scavenging ratios. These samplers were in operation during
the period 8 July through 17 August. A total of 73 wet/dry samples were obtained during the operational period along with 146 air filters, and 50 sequential rain samples. As with the network total rain samples discussed above, the wet/dry and sequential rain samples are filtered resulting in a doubling of the sample size for chemical analysis. The operations of this sub-network yielded a total of more than 800 samples for routine analysis in the chemistry facility.

AIRFLOW

The AEC, with supplemental funding from the Defense Nuclear Agency, provided a considerable portion of the expendables for this operation. This program was described by Adam et al. (1973) and Semonin and Gatz (1974). The 1974 operations involved the release of approximately 260 radiosonde flights from 3 sites. The locations of the ground recorders were at Pere Marquette, the Granite City Army Depot, and Freeburg, Illinois. These locations provided a line of observing stations oriented NW - SE across the research circle. More than 2200 pilot balloons were released from an additional 8 sites scattered throughout the research circle in a manner to allow the determination of the divergence field in proximity to the major urbanized area of St. Louis and to calculate air trajectories near convective storms.

TPS-10 RADAR

This vertically scanning radar was used extensively, as in previous years, to assist in directing the aircraft operations. During tracer missions, the data were acquired on 16-mm film for subsequent analysis. The radar was operated during the period 8 July through 18 August for the purpose of directing
the aircraft and only sporadic data are available. After the cessation of
the tracer operations and through 30 August continued routine operations over
the METROMEX research circle provided data on all storm systems.

ANALYSIS EFFORT

The results obtained from the preliminary analysis of the data from
the first 2 years of the field effort have been summarized in the report by
Huff (1973). A similar report is in preparation containing case study
analyses of several storms during the years 1971, 1972, and 1973. This report
will be available in late 1975, and will be distributed at that time.

This summary of the analysis effort contains a status report of the
various data collected during the 1974 field effort, and summarizes the total
data collected during the first 4 years of the project.

AIRCRAFT DATA

The primary function for the aircraft services during the past 4 years
has been to release tracer chemicals into the updrafts of convective and other
precipitating systems. These operations are entirely dependent upon the
occurrence of precipitation approaching or within the sampling area, and it
was necessary to have alternate missions for the aircraft for those periods
of time when precipitation was not imminent.

The urban area offers the opportunity to use many of the natural and
anthropogenic aerosols as tracers for the scavenging research. It is desirable,
therefore, to characterize the aerosol concentration as a function of varying
synoptic weather conditions. In addition, observations of the structure of
convective clouds of all types are valuable to achieve the goal of a convective cloud model for the scavenging prediction.

A very cursory examination of the 1973 and 1974 aircraft data show that a most comprehensive set of measurements were obtained and the analysis program to examine the data in detail is under way. The measurements obtained while in flight are recorded in strip-chart form and require considerable editing, and handling before the data can be used for either case study or modeling research. The charts for the previous years of METROMEX have been partially hand-analyzed for discrete portions of the records. As we anticipate the final year of field experiment, it is appropriate to begin the reduction of all of these data for the final analysis and interpretation of the full 5 year project.

The aircraft data analyzed thus far have shown results which are useful for the guidance of the tracer operations as well as having direct application to the overall METROMEX studies of precipitation scavenging. An examination of a few of the variables recorded during aircraft missions has revealed the following: 1) the existence of a measurable temperature anomaly over the urban area of St. Louis at an altitude of 450 m; 2) the discernment of the urban plume by condensation nuclei concentrations which are in excellent agreement, when properly interpreted, with cloud condensation nuclei observations; 3) discrete sources of ice nuclei have been identified; and 4) the recognition that many convective storms in the area feed upon multiple updrafts which is extremely important for understanding the scavenging process in Midwest thunderstorms.
The interpretive analysis of the chemistry data obtained from the various network operations has been directed toward their use in a limited number of case studies. To facilitate the interpretation of all of the chemistry data, the laboratory results have been formatted for computer processing to produce statistical information as well as useful data for individual storm studies. Some examples of the results from tracer experiments have been shown by Semonin (1972, 1973) and Gatz (1974a). The results from the scavenging ratio measurements have been given by Gatz (1973, 1974a) and the utility of the data in determining the urban source strength is given below.

The spectrometer data were used to demonstrate the differential average drop-size between rural and urban convective storms (Semonin and Changnon, 1974), but the data have not been mated with the chemistry to identify the role of precipitation particle size distributions and chemical concentration of various elements. All of the available spectrometer data are undergoing editing and processing for incorporation into the data bank of weather variables for the scavenging analysis.

Our air filter samples are collected to measure atmospheric concentrations of elements residing on particles, for comparison with concentrations of the same elements in rain. However, these data on elemental concentrations in air can also be analyzed to provide estimates of two important parameters that relate to the source term in mass budget equations applied to "atmospheric constituents.

The first of these parameters is the source coefficient. A source coefficient is the fraction of the total aerosol concentration at a given receptor contributed by a particular kind of source (e.g., wind-raised soil
dust or automobile exhaust). Evaluation of source coefficients for all measurable source types, both natural and man-made, at a given receptor, puts into perspective the pollution problem at that particular site, in that it indicates the relative contributions of all known sources to the total aerosol concentration. Such information makes it possible to evaluate alternate abatement strategies.

The second source parameter that may be estimated from filter measurements is the area-wide emission vote of the various elements measured on the filters. Knowing the emission rate (in tons/yr) of Pb, say, in the St. Louis area allows us to put our measurements of wet and dry deposition of Pb into perspective against the amount of Pb released. This provides the kind of information necessary to make statements about how much of a given element was released into the atmosphere in a given area in a given time, what fraction was deposited within some distance of the source, and what fraction left the area. Such information is important to assessments of elemental pathways through the environment to man. Examples of these analyses have been given by Gatz (1974b).

AIRFLOW DATA

The numerous rawinsonde and radiosonde data acquired during 1974 have been checked, edited, and are now undergoing computer processing. The computer output consists of a plot of temperature and humidity as a function of altitude for every contact point of the radiosonde baroswitch. These observations are being used for the various case studies which are under investigation and examples of their utility were given by Grosh and Semonin (1973).

The pilot balloon observing network data are vital for the determination of the scavenging efficiency of convective storms as they traverse the
research area. These data, in conjunction with the radiosonde data, are used for the calculation of the precipitation efficiency of storms as shown by Grosh and Semonin (1973). The trajectories of the airflow determined from the network measurements are also useful to separate urban-affected storms and those that can be treated as control storms.

Examples of the utility of the data in estimating the effect of the urban region on the airflow have been given by Ackerman (1972, 1974). The convergence of the low-level flow in response to the urban heat island and structural shape is an important concept for consideration in numerical efforts to simulate the urban environment and its effect on the atmosphere.

The analysis of these data, thus far, has been dictated by specific need in case studies of selected storms (Grosh and Semonin, 1972), and airflow situations (Ackerman, 1974). While funds were allocated for partial support of this extremely important observational effort, the total analysis and interpretation of the data must await the termination of the field project or the acquisition of additional funding.

TPS-10 RADAR DATA

This radar is used to assist in directing the aircraft operations and to provide observations of the 3-dimensional structure of storms of interest. The data were acquired by 16-mm time-lapse photography and consequently the task of reducing all of the data is enormous since it is manually reduced. However, select portions from the operational period are carefully analyzed to assist in the determination of water budgets in the tracer-treated storms. The tediousness of such analysis has precluded the completion of many cases and only two examples are presented in the paper by Grosh and Semonin (1973).
Considerable effort is yet to be expended to incorporate the radar information including the University of Chicago data into the interpretation of all of the tracer cases. Future operations will not require this type of data analysis since the new FPS-18 radar system will be programmed to automatically record, on magnetic tape, the 3-dimensional storm structure at 5 minute or less intervals. These data are recovered by computer techniques and will accelerate this vital part of the analysis effort.

SUMMARY OF PROGRESS

The assessment of the scavenging efficiency of convective storms is dependent upon the availability of the chemistry analysis of the various samples acquired in the field as well as all of the supporting data from the other various components of the field project. The progress toward completion of the 1974 data and data acquired in previous years was significantly delayed in 1973. The work load in the laboratory had outstripped the facility and the Water Survey invested considerable funds into the renovation of the laboratories. The laboratory modifications completed early in 1974 caused a considerable loss of analytical work. The new facility, however, allows an acceleration of effort and the analysis will soon be abreast of the data collection.

Approximately 12 case studies of convective storms have been completed and are in the editing process at the present time. These studies will bring together the data from all aspects of the Water Survey effort and will also include measurements from other groups as they pertain to the individual case under investigation.
The research studies of the aerosol characterization in the St. Louis area have shown that useful results can be obtained from a minimum network of sampling stations. The results have also shown that more fruitful work can be accomplished with the realignment of a few of the sampling stations. This type of finding is useful and will allow more representative samples for the final year of the field effort and will also allow more intelligent placement of instruments in the future for work of a similar nature.

The surface rainwater network data show that the 1800 km² area is too small to determine the total budgets for various chemical elements, but they also indicate that sufficient material is collected to permit realistic estimates of the areal deposition rate and thus useful data for verification of numerical modeling efforts.

PERSONNEL

The Principal Investigator, Richard G. Semonin, has devoted 60% of the past 12 months to the conduct of this research.

REFERENCES


APPENDIX A

Reprints, Reports, and Presentations

1971 - 1974
APPENDIX A

Reprints, Reports, and Presentations
1971-1974

Reprints


Reports


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APPENDIX B

AEC-1199

Reports, Reprints, and Preprints
APPENDIX B
AEC-1199
Reports, Reprints, and Preprints


A collection of papers, 1974:

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