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# RADIOLOGICAL AND ENVIRONMENTAL RESEARCH DIVISION ANNUAL REPORT

## Ecology

January—December 1973

REPOSITORY Argonne Lab
ER Division
COLLECTION Annual Reports
BOX No.
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ARGONNE NATIONAL LABORATORY, ARGONNE, ILLINOIS

Prepared for the U.S. ATOMIC ENERGY COMMISSION
under Contract W-31-109-Eng-38

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## FOREWORD

The Ecology Section, comprising the Great Lakes Radioecology, Thermal Studies, and Terrestrial Ecology Groups, has the overall objective of predicting the environmental behavior and ecological effects of energy-related effluents in the Great Lakes region. During 1973 there were no major organizational changes in the Ecology Section, and the number of staff members remained the same as last year.

The Great Lakes Radioecology Group continued investigations of toxic trace elements and of radionuclides in the Great Lakes, with emphasis on natural radionuclides and long-lived artificial ones in Lake Michigan. This program on the biogeochemical cycling of these elements is a joint effort between Argonne and the University of Michigan's Great Lakes Research Division.

The Great Lakes Thermal Studies Group continued studies of the effects of heated discharges from the Point Beach Nuclear Power Plant on Lake Michigan fish. The group has recently concentrated its efforts on development of radiotelemetry methods for tracking the movements of fish in the vicinity of thermal discharges.

The Terrestrial Ecology Group completed studies of tritium behavior and radiation stress in terrestrial ecosystems, and began redirecting efforts toward assessment of the economic impact of air pollutants upon agricultural crops in the Great Lakes region. Sulfur dioxide was chosen for initial study because of its current and projected importance as an air pollutant in the northeastern part of the United States.

The contributions to this report are grouped by program, each with an introduction summarizing major accomplishments during the year. Publications by the staff of the Ecology Section during 1973 are listed at the end of this report.

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# TERRESTRIAL ECOLOGY: INTRODUCTION

C. F. Jordan

During the past year there has been a major shift in emphasis in the Terrestrial Ecology Program. The tritium studies that were under way were completed, but no new tritium studies were undertaken. Jerry Kline, who had been working with tritium as a tool for measuring transpiration, began a two-year leave of absence from Argonne, and is working in the Environmental Specialties Branch of the U.S. Atomic Energy Commission in Washington, D.C. Carl Jordan had been commissioned by the Office of Information Services, U.S.A.E.C., to write a critical review of tritium in ecosystems, and that project, which required one-half a man year, was completed. A portion of the summary and conclusion section of this critical review are included in this report.

Also completed were the studies of radiation effects on photosynthesis, respiration, and carbohydrate metabolism that were being conducted in conjunction with the North Central Forest Experiment Station, Rhinelander, Wisconsin.

The new direction of the Terrestrial Ecology Program at Argonne is toward evaluating the economic impact of non-nuclear energy sources upon agricultural crops. This new direction is taken in anticipation of the Atomic Energy Commission's possible new role in a national energy agency. The importance of evaluating non-nuclear costs relative to the environment, has been stated succinctly by C. L. Comar[1] as follows: "Gofman and Tamplin deserve full discredit .... for promoting the simplistic theme that if nuclear power is not developed, then society will be spared the associated or equivalent biological cost. Obviously, in the near term if we don't have additional electricity produced from nuclear fuel, we must have it produced from fossil fuel or not produced at all. The real question is, which of these three options has the lowest biological and environmental cost? The answer is not at all clear. This

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is mainly because although we are beginning to appreciate that there are real costs of combustion of fossil fuel, there is practically no data base at all for the two non-nuclear options, as compared with that from several hundreds of millions of dollars spent on research on the biological effects of radiation.

In general terms, we are becoming a resource-limited society. Some risks and some costs must be accepted by society for the services it needs or wants. If we are to make logical decisions, we must have information about the risks of all options of accomplishing a given objective, including the risks of abandoning the objective."

The first project undertaken by the Terrestrial Ecology Group will be to evaluate the impact of sulfur dioxide on photosynthesis, respiration, and production of soybean plants, and to measure changes in quality of protein and carbohydrate in the soybean fruit following $SO_2$ exposure. The studies will be in cropped fields in which plants in replicated open top cylinders nine feet in diameter will be subjected to various levels of sulfur dioxide during the growing season.

Agricultural ecosystems were chosen as a first object of pollution study for several reasons: First, agricultural crops are much more important economically in northern Illinois than are products from other types of ecosystems. Second, there has been some criticism of past A.E.C. experiments on radiation effects on ecosystems, due to the fact that the experiments could not be duplicated. This was a result, in part, of the heterogeneity of the ecosystems irradiated, such as the tropical rain forest in Puerto Rico. Because of the uniformity of an agricultural ecosystem, biological variables are minimized, and physical variables affect the entire ecosystem more or less uniformly.

Soybeans were chosen as a crop for study because of their rapidly increasing importance as a human protein source, and because in a preliminary scan of the sensitivity of various crop plants to $SO_2$, Jordan[2] found that beans had an average sensitivity, while field corn and sorghum, the other important agricultural crops in Illinois, were much less sensitive.

Sulfur dioxide was chosen as a pollutant because of its current and projected importance as an air pollutant. The projections for coal use and

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associated $SO_2$ emission indicate that both will increase in the next decade in the U.S. (Tables 1 and 2). Unpolluted air has an $SO_2$ concentration of about $3.5 \times 10^{-3}$ ppm [4] The highest annual averages of $SO_2$ in urban areas in the United States now are close to $1.5 \times 10^{-1}$ ppm, and periodically the concentrations exceed 1 ppm.[5] Chicago is one of the cities in the U.S. most affected by $SO_2$[5] (Figures 1 and 2), and pollution extends well beyond the city limits[6] (Fig. 3).

TABLE 1.

DEMAND FOR ENERGY BY SOURCE, 1960, AND MEDIUM PROJECTIONS FOR 1980 AND 2000

| Source | Physical Quantities | | |
|---|---|---|---|
| | 1960 | 1980 | 2000 |
| Petroleum (billion barrels) | | | |
| Used in internal combustion | 2.14 | 4.06 | 8.16 |
| Used in external combustion | 1.05 | 1.28 | 1.87 |
| Total petroleum | 3.19 | 5.34 | 10.03 |
| Natural gas (trillion cubic feet) | 12.87 | 23.47 | 32.78 |
| Natural gas liquids (billion barrels) | .34 | .75 | 1.56 |
| Coal (million tons) | 436 | 630 | 718 |
| Hydro power (billion kilowatt hours) | 149 | 283 | 363 |
| Nuclear power (billion kilowatt hours) | - | 400 | 2,400 |

TABLE 2.

ESTIMATES OF CERTAIN GASEOUS POLLUTANTS PRODUCED FROM COMBUSTION OF COAL IN 1960 AND PROJECTIONS FOR 1980 AND 2000, ASSUMING NO IMPROVEMENT IN POLLUTION CONTROL (millions of pounds)

| Use | Estimate - 1960 | | Projections | | | |
|---|---|---|---|---|---|---|
| | | | 1980 | | 2000 | |
| | Nitrogen Oxides | Sulfur Oxides | Nitrogen Oxides | Sulfur Oxides | Nitrogen Oxides | Sulfur Oxides |
| Electricity generation | 4,160 | 15,808 | 8,140 | 30,932 | 9,140 | 34,732 |
| Manufacturing | 3,040 | 5,776 | 3,380 | 6,422 | 4,400 | 8,360 |
| Commercial | 176 | 1,672 | 72 | 684 | 64 | 608 |
| Residential | 160 | 1,520 | 88 | 836 | - | - |
| Total | 7,536 | 24,776 | 11,680 | 38,874 | 13,604 | 43,700 |

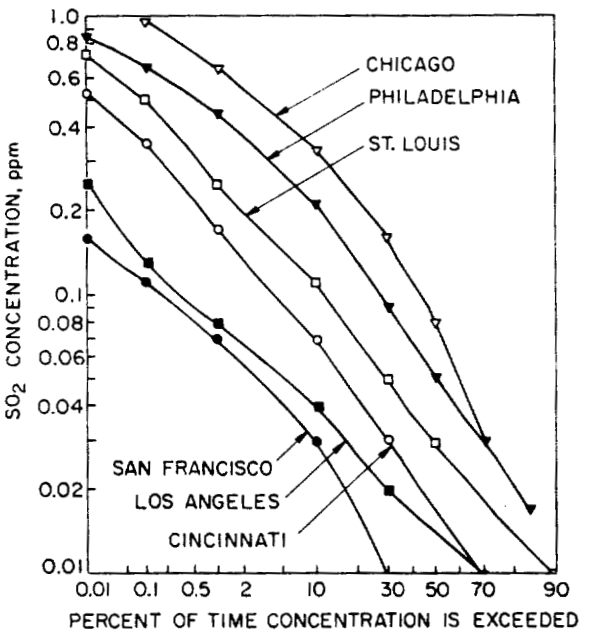


FIG. 1.--Frequency distribution of sulfur dioxide levels in selected American Cities, 1962 to 1967.[5]

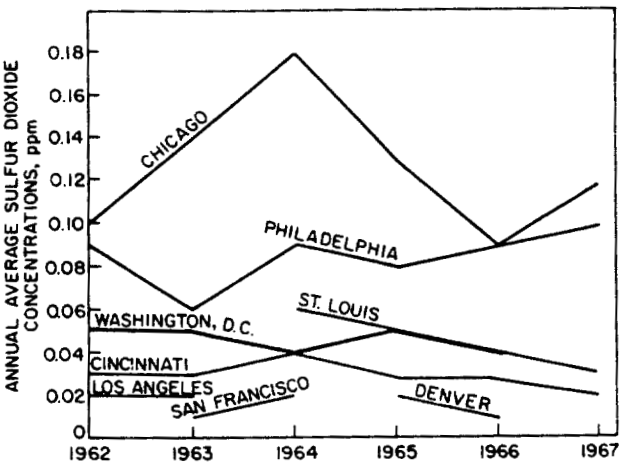


FIG. 2.--Trends in sulfur dioxide concentration for eight cities.[5]

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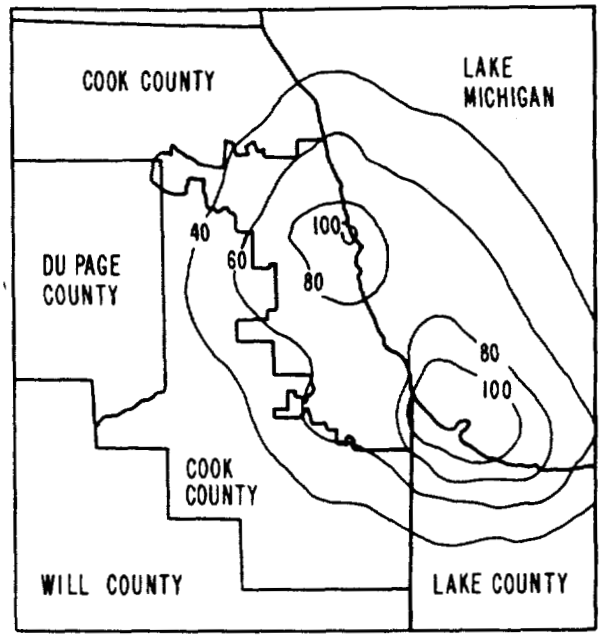


FIG. 3.--Predicted mean concentrations of sulfur dioxide around Chicago, Ill. and Gary, Ind. in $\mu g/m^3$.

There are n-X combinations of n pollutants and X crops that can be tried in future experiments, using almost the same equipment and apparatus put together for the $SO_2$-soybean experiment. Combinations actually tried will depend on the results of our first experiments and similar experiments being conducted throughout the country. Once biological variables are better understood in relation to air pollution, the experiment can be moved to more heterogeneous, natural ecosystems.

During the past year, two new people were added to the project to participate in the studies of air pollution effects on crops. Dr. M. S. Berigari, who received his Ph.D. in 1973 from North Carolina State University began preliminary work on the effects of sulfur dioxide on protein content of plants; and C. Feickert has begun work on the engineering aspects of the systems for sulfur dioxide delivery, crop exposure, and monitoring.

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# SUMMARY AND CONCLUSIONS SECTION OF "TRITIUM IN ECOSYSTEMS"—A CRITICAL REVIEW*

C. F. Jordan

Several phenomena have continually appeared and reappeared in every major ecosystem compartment as the dynamics of tritium in ecosystems have been examined. Because of the apparent universality of these phenomena and their reoccurrence in all ecosystems and ecosystem compartments, they are mentioned here once again.

The first phenomenon is the ecological importance of tritium in the HTO molecule as compared with tritium in other molecular forms. The second is the dynamics of turnover of the bulk of the HTO in every ecosystem component, which is the same as that of the free water in that component. The third is the movement of HTO molecules between components due to exchange. Net HTO movement due to exchange can proceed at a rate and in a direction independent of the transfer of $H_2O$ molecules, and it may or may not coincide with the transfer of $H_2O$ molecules. The fourth is the binding and incorporation of tritium in each component. The quantity bound or incorporated is a function of the length of time that the tritium molecules remain in that component.

It is now appropriate to discuss the situation which, in light of all the factors mentioned in this report, seems most likely to result in a tritium delivery to man which would be higher than anticipated.

If the contamination of a pasture or crop following a single release of tritium were due primarily to rainout, some of the HTO would be exchanged into the plant directly, but most of the tritium would move into the soil, where it would move out with a half-time in the order of a few weeks. About one percent of the tritium in the soil would be exchanged or absorbed into the clay. In the plants, loss through transpiration of the tritium taken up by exchange from the atmosphere would result in a very fast first component of the tritium die-away curve. However, because of uptake of tritiated soil water

*Prepared for the U.S.A.E.C. Office of Information Services.

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by the plants, subsequent die-away components for tritium in plants would be much longer in the order of weeks. There would be an even longer component due to uptake by the plants of the one percent or so of tritium initially exchanged or adsorbed onto the soil. As a result of the relatively long exposure to tritium, there is time for the specific activity of tritium in bound material of plants to approach the specific activity in the water passing through the plants. Of the tritium which is bound in plants, a large proportion will be incorporated into the organic compounds of consumer organisms.

Because tritium which is bound or exchanged in the soil, plants, and primary consumers has not been included in the estimates of the ultimate dose to man following an acute release of tritium, the estimates are low by some factor. It may be possible to compensate for this factor as follows: We know that less than two percent of the tritium moving through an ecosystem is bound or adsorbed following a single, acute release. The remaining 98 percent, upon which the dose estimates have been based, moves rapidly through the system with a turnover time equal to that of the free water pool. The two percent, however, remains in the ecosystem for a relatively long time, possibly an entire growing season, or even longer in mature ecosystems. Some of the tritium will be transpired away, but some of it will be bound in the food of man, and some of what is bound in the food will become bound in the body of man. Therefore, in a situation in which adsorption and binding processes take place, a conservative correction factor for estimating total tritium delivered to man would be obtained by assuming that the additional amount of tritium in all the food that man eats from a contaminated ecosystem would be equal to two percent of the tritium that entered the ecosystem on a unit area basis.

In the case of a grass-cow-milk food chain contaminated from the atmosphere, the assumption might be that two percent of the activity in the initial pulse passing through the grass would be bound or adsorbed and therefore available to the cow for as long as that particular crop of grass was alive. A food chain which included meat animals would be similar in that the meat animal would be continuously ingesting the bound tritium. However, instead of the tritium being passed along regularly to the population, as is the case

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with the grass-milk-man chain, the tritium would be passed along all at once.

In the case of a vegetable- or grain-to-man food chain where there is essentially only a single harvest, the total tritium to man would be increased by two percent over the amount calculated on the basis of free water turnover, but it should be remembered that since the two percent is passed along as bound tritium, most of it will be incorporated in the body of man and will not turn over with the body water pool.

The purpose of this monograph was to review the dynamics of tritium in ecosystems in order to determine the possibilities of unexpected concentrations or accumulations in food chains following accidental or deliberate release of tritium by man. It was shown that the only mechanisms that increase total amounts of tritium in organisms or ecosystem compartments over and above amounts due to the movement of the free water pool were exchange and binding. Following a discreet release of tritium, the amount bound or exchanged is very small, but following continuous release, the amount bound or exchanged is very small, but following continuous release, the amount bound and exchanged in the body could be similar to the amount in the free water pool. Inasmuch as dose estimates for current levels of tritium release were well below critical limits, failure to include bound tritium in dose calculations is not now particularly significant.

In conclusion, on the basis of a review and synthesis of over 350 studies of tritium in the environment, it can be stated that no significant ecological accumulation or concentration processes have been found that would result in tritium presenting an unexpected hazard.

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