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Exposure Data for the
Study of Acute Health Effects of Air Pollution

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Abstract

The use of aerometric network data has been criticized before on the grounds that it might give an unreliable picture of population exposure. However, the extensive data obtained from networks is still being used for studies of health effects of air pollution. This study uses a rigorous approach in analyzing these data to test their suitability for studies of acute health effects of air pollution.

New York City, with one of the most extensive aerometric networks, consisting of 40 air pollution monitoring stations, is taken as an example. Three years of hourly SO_2 readings and bi-hourly readings of smokes shade have been analyzed. The use of one aerometric station to represent the daily exposure of the population of New York City as has been done in previous studies is shown to be invalid. The use of individual monitoring stations of the New York City aerometric network to represent the day-to-day exposure to SO_2 and smokes shade of the populations surrounding these monitoring stations is examined, with results showing that further work will be necessary before such an approach is justified.

Introduction

There is by now a vast literature describing studies in which daily levels of mortality and morbidity in a specified geographic area, such as a large metropolitan complex, have been related to daily levels of air pollutants as measured usually by one aerometric station in that area. There is by now also a growing body of literature criticizing these approaches. When mortality has been used as an indicator, it has been argued to be an inappropriate and insensitive measure of short-term health effects. If morbidity data has been used their reliability has often been questioned. In addition more and more questions are being raised about the independent variables that have to be entered into the equation:

Pollution → Health Index

How reliable are the measurements of air pollution? The APCA held a specialty meeting in New Orleans in October 1975 in which the problem of the reliability (precision) of air pollution determination was discussed. J.B. Clements et al¹ reported on the Environmental Protection Agency's active program in the evaluation of air pollution measurement methodology. As an example, information about precision from collaborative testing results was obtained, in which 14 participants from federal, state and local air pollution agencies, universities, and industrial corporations were directed to use the E.P.A. reference method for measuring SO₂ in the test atmosphere. The authors summarized the results: "The results indicated that the pararosaniline SO₂ method is not quite as precise as desirable. From considerations discussed in the report on the collaborative test, the following statements can be made about the method (a 95% confidence level is assumed):

1. For two single observations by the same analyst, differences of 20% or more may be detected at an SO_2 concentration of $300 \mu\text{g}/\text{m}^3$ (approximately .105 ppm).

2. The method cannot detect differences of less than 20% between single observations of two laboratories in the range of 0 to $1,000 \mu\text{g}/\text{m}^3$. At a level of $100 \mu\text{g}/\text{m}^3$, the difference of less than 100% is not detectable." (Present levels of SO_2 in New York City are approximately $100 \mu\text{g}/\text{m}^3$).

In general the papers at the meeting emphasized the need for further studies of air pollution measurement methodology, and the need for recognition of the lack of precision of measurements as they now exist when compliance with regulatory standards is being examined. There is no need here to emphasize these points when the same data is used in health studies.

But these studies only refer to the reliability of two or more measurements performed either by a single investigator or by several investigators on a single sample of air. How about the question of how representative a single aerometric station is of the day-to-day changes in levels of air pollution of the entire geographic area supposedly represented by the station? Buechley's ² study used one station to represent the daily levels of air pollution of the entire New York-New Jersey-Connecticut metropolis. Schimmel et al ^{3,4,5} and Hodgson ⁶ have used one station in New York City and related these measures to daily levels of mortality throughout the five boroughs of New York City. This is a question that will be addressed in this paper.

Another question that arises about the independent variable is the choices of pollutant that will be used in the relationship: Air Pollution $\longrightarrow$ Health. There are thousands of chemicals in the air, and it is well

known that it is not necessarily the most abundant of all pollutants or the most easily measured that is the most harmful.

Most studies have related sulphur dioxide to some health index. Sulphur dioxide is an abundant, easily measured pollutant which can be detected by its characteristic odour. Recently this approach has been considered simplistic, since, based on animal and human experiments, sulphur dioxide in isolation in concentrations comparable to sulphur dioxide levels in the United States does not seem to have any deleterious effect on health. Some toxicological and epidemiological studies have however suggested that sulphates which are the end products of atmospheric oxidation of SO_2 may have harmful effects. The question of health effects of sulfates or sulfites (both products of sulphur dioxide in the air) is not yet answered, but the evidence of irritant effects on the respiratory tract in Amdur's⁷ experiments on guinea pigs is strong. What is striking about these experiments is the sensitivity to which particular sulfate the animals are exposed, and even more remarkably, the extraordinary sensitivity to the particular size of the sulfates.

Thus the measure of "respirable particulates" that is currently used to relate to health effects is too coarse for meaningful estimates of the adverse health effects, since the smaller "respirable" particles seem to have a larger physiologic effect than the larger "respirable" particles. Amdur has also shown that the presence of certain trace metals in the form of soluble salts in the atmosphere were strong potentiators of the response to sulphur dioxide. Synergism between ozone and sulphur dioxide has been demonstrated by Bates⁸ in human subjects exposed to 0.3-0.4 ppm of these gases.

It seems that while ozone and sulphur dioxide do not react at low concentrations unless olefins are present, they are very likely to react in the moist atmosphere of the lung to form sulfuric acid.

This introduction was just given to highlight the complexity of the problem and the tremendous amount of work that will have to be done before meaningful studies can be carried out. After many millions of dollars spent, one must conclude that the variables employed are too crude and unreliable. The result has been that different epidemiologic studies have yielded such conflicting results, at least in the United States, that almost any question that can be raised can be given diametrically opposing answers.

It is clear that a great deal of thought and research will have to be devoted to this field in the future, before meaningful results about the relationships between air pollution and health can be obtained.

Materials and Methods

We set out in 1970 to design a health and air pollution study to overcome two major problems that accompanied all previous studies carried out in New York City and elsewhere. First, these studies failed to take proper account of weather, which itself has been shown to influence health⁹, and is also known to be highly correlated with air pollution. Cold or extremely hot weather, for example, which are known to be stressful to certain susceptible individuals even in the absence of pollutants, are known to result in higher power consumption for heating and air conditioning, thus causing the emission of more pollutants in the air. Previously, studies in New York City that have taken account of the confounding effect of weather have relied on statistical methods to correct for

the health effects of weather. Our study design uses an epidemiologic method to control for the effects of weather. Thus we selected two areas in New York City with populations of comparable socio-economic and racial compositions and with similar day-to-day weather conditions but different in their daily levels of air pollution.

A second shortcoming of previous studies, as we have pointed out, was the use of one aerometric station to represent the day-to-day variation in air pollution experienced by the entire population of the five boroughs of New York City. Schimmel, in his latest study ⁵, in concluding that SO_2 has very little acute effects on daily levels of mortality in New York City, has used the data from only one station to represent the daily dosage of SO_2 and particulates (coefficients of haze) for his independent variables. New York City has a forty-station aerometric network scattered fairly uniformly throughout the five boroughs. It was our intention to use the data from the stations of the aerometric network situated within our two study areas to monitor the daily levels of air pollution that the population residing in these areas were exposed to (see Map, Figure 1). The conclusion from our preliminary analysis ^{10,11,12} of air pollution data from the forty-station aerometric network for the period 1969-1971 can be summarized as follows:

The use of one aerometric station to represent the daily fluctuations in air pollution throughout the five boroughs of New York City is not justified for the following reasons:

- (1) Based on 40x40 correlation matrices obtained for all pairs of stations of the aerometric network, the correlations between pairs of stations was low, ranging from -0.6 to +0.9 and averaging

around 0.5 for SO_2 and 0.4 for smokes shade. These results can be seen in Figures 2 and 3, which represent histograms of the number of correlations having a given value for sulphur dioxide and smokes shade, respectively, obtained between pairs of stations for the winter seasons for the period 12/68-2/72.

- (2) There was no consistency of correlation coefficients between pairs of stations from one season to another and in the same season in another year. In other words, a given pair of stations might show a high correlation in a given season but will not in another season; neither will they show a high correlation in the same season in a different year.
- (3) When height of stations above ground or sea level is taken into account, this does not result in a better correlation coefficient between them; in other words, pairs of stations that are both low or both high above the ground or above sea level do not correlate any better with each other than do pairs of stations that differ considerably in their height above ground or above sea level.

The reason for the above-described poor correlations are not yet fully understood and will be subjected to further analyses. But the fact of the poor correlations remains.

The results of these analyses on the New York City aerometric network strongly confirm the conclusion of our earlier paper that the procedure of using one aerometric station to represent air pollution exposure of a population of a large geographic area, and which is still currently used in studies of acute health effects of air pollution, is extremely risky in that it provides an uncertain measure of the short-term variation in

air pollution that the population in the area is exposed to.

Results

In our study we used data from the forty-station aerometric network of New York City as the source of air pollution data representing the local areas surrounding the stations. Two areas, Harlem and Bedford-Stuyvesant, were chosen for study. They are almost identical in social and demographic variables and may be presumed to have similar weather conditions, but according to data of the aerometric network, differ in day-to-day variations in pollution levels. To monitor health effects, daily visits for respiratory illnesses to hospital emergency rooms in these geographical areas have been chosen as dependent variables.

In our study areas there are five monitoring stations: two situated in Harlem #00 and #2, and three in Bedford-Stuyvesant, #18, #19, and #11 (see Map, Figure 1). The appropriate area covered in the emergency room population for Harlem is 3 1/2 square miles. We hoped that measurements from these stations could be used to represent the daily exposures of the population residing in these areas. On examining the correlation coefficients between various pairs of the stations situated in these two areas we were dismayed to find that the correlation coefficients between neighboring pairs of stations were no higher than between pairs of stations situated in widely separated parts of New York City. It should be noted that these observations do not contradict the observation that pollution in Harlem is on the average higher than in Bedford-Stuyvesant.

This surprising failure of the day-to-day variation in pollution at adjacent stations to correlate any better than at distant ones led us to study the dependence of the correlation coefficients as a function of

spatial separation between stations. The distances were calculated from the geographical positions of the stations as expressed relative to a coordinate grid obtained from the Department of Air Resources. The results are summarized in Figures 4 and 5, which represent histograms of average correlation coefficients for sulphur dioxide and smokes shade respectively at all pairs of stations in the New York City aerometric network as a function of distance in kilometers between stations for the fall seasons during the period 12/68-2/72. As can be seen from these histograms, correlation coefficients do not increase by any appreciable amount with greater proximity of stations. The range of correlation coefficients at each distance of separation was from negative to a high positive correlation. Thus the reasonable expectation that near-by stations would correlate better than distant ones is not fulfilled.

To explain the above described low correlation coefficients obtained between daily average levels of pollution measured at all pairs of stations of the New York City aerometric network, we performed some preliminary crude analyses to investigate the relationship between correlation coefficients between pairs of stations lying in the direction of the prevailing wind and out of the wind direction. When the wind direction was within $\pm 20^\circ$ from the line joining a pair of stations, the pair was defined to be within the direction of the wind. All other stations were defined to be out of the direction of the wind. (Wind direction used is the prevailing wind direction obtained from the National Weather Service, Asheville, North Carolina for Central Park 6-9 AM readings from tape reference #BAS-14. The 9-10 AM readings at each station for sulphur dioxide were used to obtain a morning average from which the correlation coefficient was calculated.) The average correlation coefficients for

stations in the wind direction turned out to be not significantly different from the average correlation coefficients for stations out of the wind direction. (The average correlation coefficients for pairs of stations lying along the wind direction and for those lying out of the wind direction were both 0.36).

The above results suggest as one possibility that the data collected in each aerometric station do not represent the pollution throughout the geographical area that these stations were designed to represent. This could be the case if the variability of air pollution at various points lying between adjacent stations is as great or greater than the variability between the adjacent stations themselves. In other words, pollution fluctuations, instead of being on a scale of kilometers, take place on a scale of meters or tens of meters.

Conclusions

Poor reliability of sulphur dioxide measurements under ideal conditions (collaborative testing) raises serious questions about the procedure currently used in the studies of acute health effects of air pollution. These methodological problems become more serious as the levels of ambient sulphur dioxide decrease, and are currently being investigated by us in terms of their use in acute health effects of air pollution studies. In addition the above results from our own work indicate that the air pollution data from the New York City aerometric network available at the present time are not suitable for the purpose of epidemiologic studies of the acute health effects of air pollution. Before such studies can be carried out, the reliability of the individual readings needs to be established, and an intensive investigation of air pollution levels between existing aerometric stations needs to be carried out. This latter

could be accomplished by the use of mobile stations, or additional stationary air pollution monitoring stations that would be placed at strategic points around existing network stations. Data from these units could then be used together with local micro-meteorological data to describe the levels of air pollution in areas surrounding stations. Once areas have been characterized in these terms, population exposure models could be constructed taking population density into account. Population exposure models would be aided by the use of personal air pollution monitors that would approximate individual exposure throughout the day as they traverse different paths (indoors and outdoors) relative to the monitoring stations.

References

1. J.B. Clements, M.R. Midgell, and J.H. Murgeson. "Evaluation of air pollution measurement methodology". Presented at the APCA specialty meeting at New Orleans, October 1975.
2. E.W. Ruchley, W.B. Riggan, V.H. Hasselblad, and J.B. Van Bruggen. "SO₂ levels and perturbations in mortality". Arch Environ Health, Vol 27 (Sept. 1975).
3. H. Schimmel and L. Greenburg. "A study of the relation of pollution to mortality--New York City 1963-1968". JAPCA 22: 607 (August 1972).
4. H. Schimmel and T.J. Murawski. "SO₂--Harmful pollutant or air quality indicator?" JAPCA 25: (7): 739 (July 1975).
5. H. Schimmel and T.J. Murawski. "The relation of air pollution to mortality, New York City 1963-72". Journal of Occupational Medicine, (April 1976).
6. T.A. Hodgson. "Short-term effects of air pollution on mortality in New York City". Environ Sci and Tech 4: 589 (1970).
7. M.O. Amdur. "Toxicological guidelines for research on sulfur oxides and particulates". Presented at the Fourth Symposium on Statistics and the Environment, National Academy of Sciences, March 3-5, 1976.
8. D.V. Bates. "The effects of low levels of SO₂ and ozone in the same atmosphere on human pulmonary function". CEC-WHO-EPA Symposium on "Recent Advances in the Assessment of Health Effects of Environmental Pollution". Paris, France, June 1974.
9. I.F. Goldstein. "Interaction of air pollution and weather in their effects on Health". HSMHA Health Reports 87: (1): 50, (1972).
10. I.F. Goldstein and L. Landovitz. "Analysis of Air Pollution Patterns in New York City - I. Can One Station Represent the Large Metropolitan Area?" Atmospheric Envir. Vol II: 47-52, 1977.
11. I.F. Goldstein and L. Landovitz. "Analysis of Air Pollution Patterns in New York City - II. Can One Aerometric Station Represent the Area Surrounding it?" Atmospheric Envir. Vol II: 53-57, 1977.
12. I.F. Goldstein, L. Landovitz and G. Block. "Air Pollution Patterns in New York City." APCA Journal 24: No. 2 148, February, 1974.

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Fig. 1 Aerometric network -- New York City.

Figure 2. Histogram of the number of correlations within a given interval for all winters combined in the period 12/68- 2/72 - sulphur dioxide.

Figure 4. Average correlations for sulphur dioxide as a function of distance in kilometers between stations of the New York City aerometric network for the fall seasons during the period 12/68-2/72.

Figure 5. Average correlations for smokeshade as a function of distance in kilometers between stations of the New York City aerometric network for the fall seasons during the period 12/68-2/72.