Weekly and Seasonal Changes in Total Suspended Particulate Concentrations at Indianapolis, Indiana[1]

James E. Newman
Departments of Agronomy and Geosciences
Purdue University, Lafayette, Indiana 47907

and

Dale E. Phinney
NOAA, EDS Laboratory for Environmental Research
U.S. Department of Commerce, Silver Springs, Maryland 20910

Abstract

Daily total suspended particulate concentrations for the period of 1968-1970 at Indianapolis, Indiana, were analyzed to illustrate the weekly and seasonal variation in urban air pollution. Weekly and seasonal changes in air quality as measured by daily total particulate concentrations are identified; comparisons are made between the maximum monthly concentrations and the mean monthly frequency of stagnating anti-cyclones. Mean annual area concentrations for daily periods as measured by 19 monitoring stations in Indianapolis and Marion County, Indiana, are illustrated. Some reasons for the recorded changes in daily, weekly, and seasonal air quality in Indianapolis are proposed.

Introduction

It is generally understood that air pollution concentrations change from hour to hour, day to day, and from one season to another during the year. These variations have many causes, some of which are well understood. Extremely high levels of air pollutants are related primarily to very stable stagnating meteorological conditions for several days. Likewise, extremely low levels are related to very unstable meteorological conditions. But the normal hour to hour and day to day meteorological change, coupled with time and space changes in human activity in a given urban area, usually produces substantial periodic patterns in air pollution concentrations. These pattern changes must be properly assessed when planning a sampling procedure for the purpose of monitoring air pollution concentrations. Sampling at fixed times and places can produce highly biased data. It is for this reason that the authors took a rather critical look at periodic changes in air pollution concentrations of total suspended particulate over a 3-year period at Indianapolis, Indiana.

Data and Methods

Data used in this study consisted of 24-hour samples of total suspended particulate concentrations from 19 locations in Indianapolis, Indiana, from January 1, 1968, through December 31, 1970. These daily values were in micrograms per cubic meter ($\mu g/m^3$). The data

[1]Journal Paper No. 4649, Purdue University, Agricultural Experiment Station.

This research was supported jointly by the U.S. Dept. HEW, Public Health Training Grant No. 5TO1AP00072-03, and Purdue University AES Hatch Project 1685, entitled "The Climatic Resources of the North Central Region."

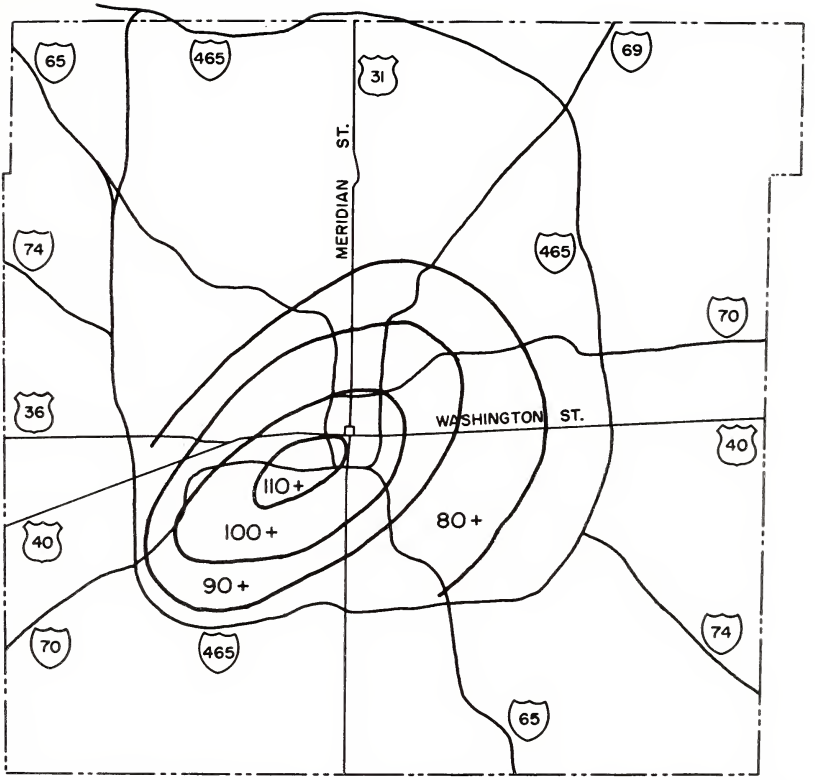

FIGURE 1. *Mean daily total suspended particulate for Indianapolis, Indiana 1968-1970.*

were recorded by the Environmental Control Division, Department of Public Works, City of Indianapolis.

Daily values representing a 24-hour period from 10 AM one day to 10 AM the following day from each of the 19 monitoring stations were averaged to produce the estimated isolines of mean daily total particulate reported in Figure 1. The total composite of daily values in consecutive 7-day weeks for the 3 years at Site 1 was 777 or 111 weekly periods. These daily values were further composited into 7-day period values for each day of the week, thus the mean value for each of the

TABLE 1. *The Analysis of variance for the composite of daily values for total particulate at Indianapolis, Indiana, 1968-70.*

Sources	D. F.	Sums of Squares	Mean Squares	F Ratio
Treatment	6	27565.0101	4594.1683	3.2704
Residual	766	1076051.2668	1404.7667	
Total	772	1103616.2768		

$F_{.05} = .210$
$F_{.01} = .280$

TABLE 2. *The analysis of variance for the composite of monthly values for total particulate at Indianapolis, Indiana 1968-70.*

Sources	D. D.	Sums of Squares	Mean Squares	F Ratio
Treatment	11	57549.0300	5231.7300	3.8060
Residual	761	1046067.2469	1374.5956	
Total	772	1103616.2768		

$F_{.05} = 1.75$
$F_{.01} = 2.18$

7 days in a weekly period is an average of 111 values. Similarly, all daily values falling within a given month were composited to produce monthly mean values. These data were subjected to an analysis of variance reported in Tables 1 and 2, and in Figures 2 and 3. Site 1 air sampling station is located near the City-County Building in downtown Indianapolis.

Results and Discussion

The National "Clean Air Act" passed by Congress in 1967 has many provisions, regulations, and suggestions as guidelines for achieving its goals. This Act clearly states that all areas within the United States shall come under the control of a State or Federal designated Air Quality Control Region. Further, the Act provides general guidelines and timetables for achieving compliance.

One of the goals as stated in guidelines, under the 1967 Clean Air Act, is that all areas in the United States should achieve an air quality, as measured by total suspended particulate matter, of 80 $\mu g/m^3$ per 24 hours for an annual mean value.

With this in mind, the authors summarized 3 years of daily total suspended particulate samples collected within the City of Indianapolis and Marion County to produce Figure 1. This figure provides an estimated geographical picture of that area in Indianapolis where the air quality exceeded that annual mean value of 80 $\mu g/m^3$ per day.

Once an air pollution problem area has been established, further monitoring must be continued to establish whether or not a geographical area has or has not achieved the goal of compliance for a given air pollutant. If one could assume that air pollution levels did not change much from hour to hour, day to day, and month to month, then only a few sampling days during the year would be adequate for establishing compliance within a given Air Quality Control Region. Secondly, if one could assume the air pollutants' changes in concentration were strictly random in time and space, then only enough samples to estimate the statistical error desired would be necessary. Unfortunately, neither of these two assumptions is likely to hold.

It is well known that air pollutants vary both in time and space. Over a yearly period or longer, variations in space are closely related to sources of pollutants in a given area. On the other hand, variations in time are closely related to changes in meteorological conditions and

the total activities of the community concerned. Since Figure 1 illustrates the mean estimated variation in space for the City of Indianapolis, the authors decided to subject the data to an analysis of variance in time at a given point. For this study, Site 1 was selected near the geographic center of Indianapolis. All daily values that were consecutive in 7-day runs over the 3-year period at Site 1 were subjected to this time-series analysis. The results of this effort are graphed in Figure 2, with the analysis of variance reported in Table 1.

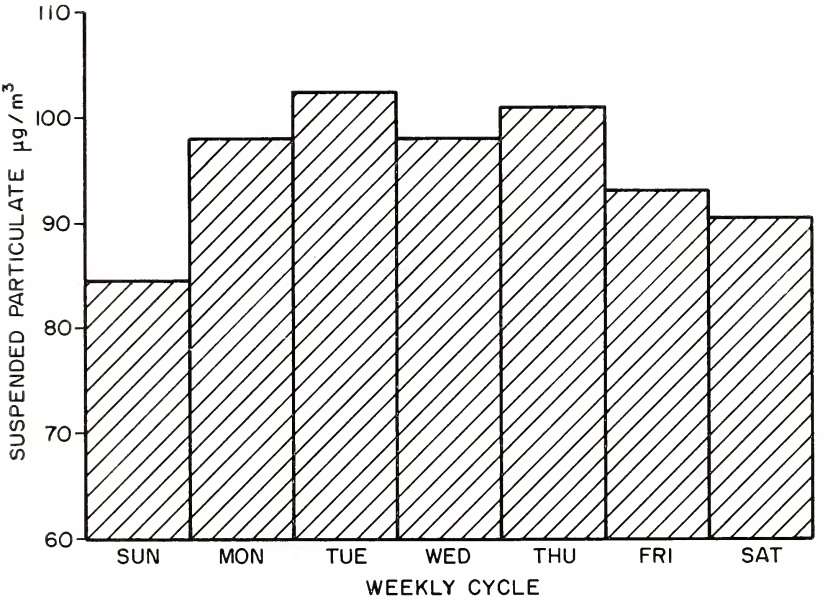

Figure 2. *Mean daily values of total suspended particulate for each day in the week at Site 1, Indianapolis, Indiana, 1968-1970.*

Figure 2 illustrates considerable change from day to day during the normal 7-day calendar week in mean daily total suspended particulate for Indianapolis. These mean changes from day to day during a weekly period are very significant as shown in Table 1. This analysis strongly suggests that taking air quality samples on one or two fixed days during a 7-day week is likely to produce biased data. The one day with the least bias in this analysis turns out to be Friday, since it is the mean daily value closest to the estimated weekly mean value.

A similar analysis was done for monthly periods. These results are reported in Figure 3 and Table 2. Here again, considerable variation exists in mean daily value of total particulate from one month to another and particularly between seasonal periods. The highest values occur during the summer season, particularly in August. The lowest seasonal values occurred in late autumn and early winter with the lowest in November.

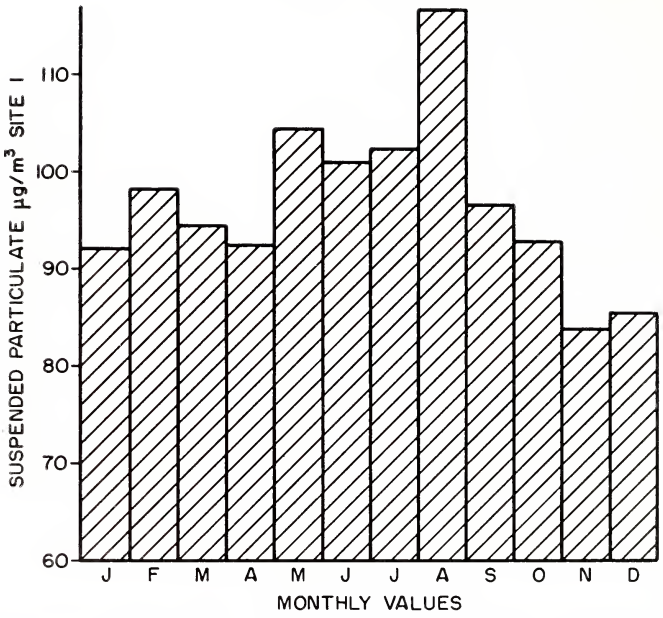

FIGURE 3. *Mean monthly values of total suspended particulate for each month, at Site 1, Indianapolis, 1968-1970.*

Variations in mean monthly values for daily total particulate at Site 1 in Indianapolis were subjected to further analysis as graphed in Figure 4. This graph reports the number of times per month that mean daily values exceeded one standard deviation above the monthly mean. Such above-normal values in air pollution concentration are

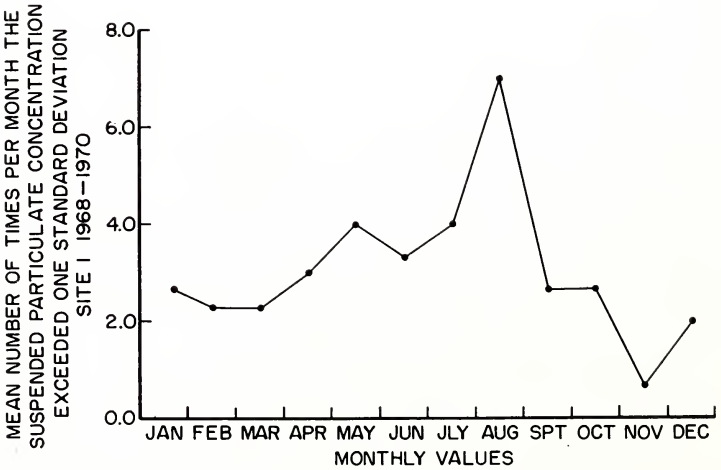

FIGURE 4. *High air pollution occurrences at Site 1, Indianapolis, Indiana, 1968-1970.*

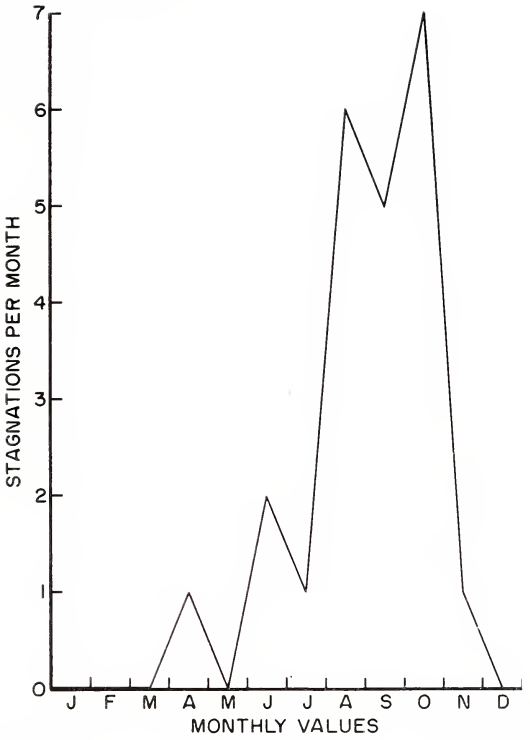

FIGURE 5. *Monthly number of stagnating anti-cyclones as reported by Korshover (1) at Indianapolis, Indiana, 1936-1965.*

usually associated with an extended period of extremely stable meteorological conditions. Therefore, it was decided to compare the results graphed in Figure 4 with the results reported by Korshover (1) on the mean number of cases per month of anti-cyclone stagnations in a 30-year period (1936-1965) for Indianapolis. Korshover's results are graphed in Figure 5. Note the unusually high number of cases in August, September, and October. Since Korshover's results represent a climatic norm, one can conclude that high levels of air pollution for extended daily periods should be expected during the late summer and early autumn at Indianapolis, Indiana.

This analysis shows that periodic sampling of air pollutants, as has often been the practice of air quality control districts, can result in seriously biased data. The reason for this possible bias is related to the fact that air pollution concentrations are subjected to periodic changes caused by the area patterns of total community activities and seasonal changes in meteorological conditions. Biased data from an air quality sampling network can be reduced by avoiding fixed sampling periods, such as one particular day per week or a particular set of days per month. Therefore, air quality samples should be taken in a manner

that minimizes the error in estimating the true mean for the period concerned.

It is generally accepted that air pollution concentrations vary from hour to hour during a normal 24-hour period. But since no hourly data existed at Indianapolis, the diurnal period could not be studied. Normally, the highest concentrations occur during the early morning hours of 7 to 9 AM, with the lowest values occurring between 1 and 4 PM.

Conclusions

From air quality data on total suspended particulate at Indianapolis, Indiana, from January 1, 1968, through December 31, 1970, it is concluded that day to day weekly variations and month to month seasonal variations are significant. Therefore, periodic sampling of air pollutants on fixed days of the week should not be practiced without proper correction procedures. Otherwise, seriously biased estimates in air quality can result.

Acknowledgements

The authors acknowledge Mr. Lewis F. Scott, Manager, and Mr. Wallace Benson, Chemist, of the Environmental Control Division, Department of Public Works, City of Indianapolis, for their many helpful discussions and suggestions concerning the data used in this study. The data were made available by the Environmental Control Division, Department of Public Works, City of Indianapolis.

Literature Cited

1. KORSHOVER, J., 1967, Climatology of stagnating anti-cyclines east of the Rocky Mountains, 1936-1965, Pub. Health Serv. Publ. No. 999-AP-34, 15 p. U. S. Dep. Health, Educ., and Welfare.