韓國環境衛生學會誌
Kor. J. Env. Hlth. Soc.
Vol. 13, No. 2, 1~7, 1987

Relation of the Pollutant Standards Index (PSI) to Total Mortality

Yoon Shin Kim

College of Medicine, Hanyang University

PSI (Pollutant Standards Index) 와 死亡率과의 관련성

金 潤 信

漢陽大學校 醫科大學

요 약

大氣汚染과 死亡率과의 관련성을 평가하고자 美國內 23개 SMSA (Standard Metropolitan Statistical Areas) 地域에서 대기오염의 程度를 나타내는 指數인 PSI (Pollutant Standards Index), 氣象學的 變數 및 社會 經濟的 變數를 이용하여 多變量 分析을 시도하였다. 그 結果 총사망율과의 관련성은 사회경제적변수가 영향이 큰 반면 PSI는 작은 것으로 示唆되었다. 대기오염과 사망율과의 연관성에 관한 평가는 많은 변수의 複雜性이 내포하고 있어 좀더 具體的이고 세밀한 分析이 기대된다.

I. Introduction

Many investigators have examined the health effects of air pollution and have raised some limitations concerning the reliability and applicability of epidemiological studies of air pollution.[1-3] Moreover, informations on health risks from polluted air are limited to the public which needs reliable and easily understandable information on the health effects of air pollution.

Recently, the U.S. Environmental Protection Agency (EPA) has developed and proposed a natural standardized index, called the "Pollutant Standards Index (PSI)", to provide this information.[4]

The PSI is defined as a highly summarized health related index that converts the pollutant concentrations in a community's air to a simple number on a scale of 0 to 500, based on five major pollutants- carbon monoxide (CO), total suspended particulates (TSP), photochemical oxidants or ozone (03), and nitrogen dioxide (NO2). The PSI will rise above 100 when any of the five criteria pollutants reaches a level judged to have adverse short-term effects on human health for one day during one year.

The health effect levels for PSI intervals are good or mederate for 0–99; unhealthful for 100–199; very unhealthful for 200–300; and hazardous for more than 300.

A number of epidemiological investigation has demonstrated a causal association of air pollution to human health.5-6) Subsequently, the numerous cross-sectional studies of mortality and air pollution have devoted to examining the relationships between geographic differences in air pollution levels and mortality rates.7-11) However, the relationships are causal, but definitely cause and effect has not shown. Therefore, the questions concerning air pollution and effects on human health have continued to be subject of intense debate,12) and in this connection it is useful to reexamine the health effects of air pollution using the available data of the past.

This paper is an attempt to examine the relationship between total mortality rates and the level of PSI, including climatic and socioeconomic conditions, based on a data for 23 SMSAs (Standard Metropolitan Statistical Areas) in the United States.

II. Materials and Methods

The data used for this study include 23 SMSAs in the United States (See Appendix A). Only the SMSAs for which the statistics on the Pollution Standards Index (PSI) were available for the years 1978–1980 were selected for the analysis. The three groups (PSI, socioeconomic, and climate) of the independent variables and total mortality rates as a dependent variable were selected for the study. The variables selected for analysis are defined as listed in Appendix B.

Data for the total mortality rates and socioeconomic status consisting of three variables as reported for 1979 were drawn from the 1982 State and Metropolitan Data Book.13) Information on climatic variables as recorded for 1975 were taken from the 1977 County and City Data Book.14) The selection of climate data was limited to those which the statistics were available for the year 1975. The 1982–1983 Statistical Abstract of the United States was used to obtain information on PSI during 1978–1980.15)

The PSI above 100 which represents adverse short-term effects on human health for one day during one year was only selected for this analysis, therefore, annual average number of days for PSI exceeding 100 during 1978–1980 was practically calculated for each SMSA.

Multiple regression analysis was performed for estimating the effects of PSI on total mortality rates controlling for several confounding factors. Regression model explaining total mortality rates was generally formed:

$$\mathrm{TMR} = u + a(\mathrm{PSI}) + b(\mathrm{TEMP}\ 1) + c(\mathrm{TEMP}\ 7) + d(\mathrm{PRECIP}) + e(\mathrm{POP\ DEN}) + f(\% \geq 65) + g(\%\ \mathrm{UNEMP}) + \varepsilon \text{ ---------------- } (1),$$

where the term μ is a constant and ε is the random error term. Using the above equation, multiple regression model was also transformed into a linear model by taking natural logarithms of each variable.

III. Results

Table 1 shows the means, standard deviations of variables selected in this study for the 23 SMSAs. Mean total mortality rates in

Table 1. Means and standard deviations of variables (N=23)

Variable	mean	Standard Deviation
Total mortality rate, 1979 (Deaths per 1,000 pop.)	8.20	1.50
Pollutant Standard Index ≥ 100 (days/year)	69.30	56.81
Mean Temperature-January (°F)	36.61	12.02
Mean Temperature-July (°F)	73.74	5.32
Annual Mean Precipitation (inch)	30.37	12.72
Population Density (persons per sq. mile)	946.30	1332.86
% Population ≥ 65	10.76	2.88
% Unemployment	6.65	1.33

Table 2. Correlation matric of the variables* (N=23)

	PSI	TEMP 1	TEMP 7	PRECIP	POP DEN	% ≥ 65	% UNEMP
TMR	-.320	-.036	.051	.417	.359	.933**	.522**
PSI		.267	.142	-.271	.117	-.381	-.033
TEMP 1			.069	-.306	-.095	.088	-.330
TEMP 7				.309	-.094	-.048	-.135
PRECIP					.376	.207	-.037
POP DEN						.239	.038
%≥65							.434

* All variables are taken natural logarithms.

** $p < 0.01$

selected SMSAs were 8.20 per 1,000 population in 1979. Annual average number of days for PSI exceeding 100 were 69 days per year. In particular, Los Angeles-Long Beach, California showed the largest days of unhealthful value of PSI exceeding 100, followed by Riverside-San Bernardino-Ontario, California.

Table 2 examines the correlation coefficients among the variables taken natural logarithms in this study. With exception of Pollutant Standards index (PSI) and January Temperature (TEMP 1), the total mortality rates (TMR) were positively correlated to other variables. Significant relationships with total mortality rates were found for percent of population of 65 years and older, and percent of unemployment. Except these two variables, none of variables were significantly correlated with each other

Table 3. Multiple regression analysis of total mortality rates

	Regression coefficient (B)	Standard error of B	Significance of B	R Change
PSI	.004	.013	.736	.102
TEMP 1	.017	.040	.669	.084
TEMP 7	.115	.152	.461	.043
PRECIP	.080	.025	.005	.057
POP DEN	.015	.012	.239	.143
$\% \geq 65$	.592	.060	.000	.267
% UNEMP	.181	.065	.013	.262
(constant)	-.571			

variable.

Table 3 shows multiple regression analysis of total mortality rates on the independent variables. Using the Equation (1), the following Equation gives the results:

$$\text{Ln(TMR)} = -.571 + .004\ \text{Ln(PSI)} + .017\ \text{Ln(TEMP 1)} + .115\ \text{Ln(TEMP 7)} + .080\ \text{Ln(PRECIP)} + .015\ \text{Ln(POP DEN)} + .592\ \text{Ln}(\% \geq 65) + .181\ \text{Ln(\% UNEMP)} \text{ ------------ } (2),$$

Adjusted R = .939, F-ratio = 49.433 ($p < 0.01$).

The percent of the variation in the total mortality rates is accounted for 94 percent. The F-ratio tests show a 1% level of significance of the overall fit.

Percent of population of 65 years and older was the most important variable, explaining 59 percent of variability ($P < 0.001$). This implicates that a hundred percent increase in the proportion of the population of 65 years and older is associated with an increase in the total mortality rates of 59.2 per 1,000 population.

The percent of unemployment was also an important variable. An increase of one hundred percent in the proportion of unemployment would increase the total mortality rates by 18 percent. In addition, the regression coefficient of mean temperature of July was greater than that of any other climatic variables. Regarding the PSI, it was suggested that a hundred percent increase in annual average days for PSI exceeding 100 would imply an increase of about 0.4 percent in the total mortality rates. In other words, one day increase of PSI exceeding 100 may be related to an increase of 0.4 percent in the total mortality rates.

A positive association between total mortality rates as a independent variable and each dependent variable was found in regression coefficients. The significance of regression coefficients in Table 3 also supports that percent of population of 65 years and older is stronly associated with total mortality. However, PSI effects is rather low among the variables. Furthermore, the results of the correlation and regression analyses do not provide any evidence about which a value of Pollutant Standards Index (PSI) is more strongly associated with total mortality rates.

IV. Discussion

To examine the effects of air pollution on total mortality rates, a new variable of PSI, as indexed by level of air pollution health effects was included in the analysis.

From the multiple regression analysis, socioeconomic and climatic variables explain a greater percentage of the variation in the total mortality rates than do PSI variable. These findings are consistent with earlier reports of strong association between socioeconomic variables and total mortality rates.16)

Percent of population of 65 years and older variable is more strongly correlated with total mortality than any other variables. This fact makes it possible to interpret with physiological etiology.

It seems that interaction of climatic factors and total mortality is complex. Regression coefficients of temperature of July explain higher percentage of total mortality rates variation than other climatic variables. Undoubtedly, influences of climatic factors found to be related to mortality.17-18)

Although the PSI was a valuable index to give the relationship of current air quality to the Primary National Ambient Air Quality Standard,19) the implementation of PSI would need further research because the values of PSI were ascertained for population exposure in a community rather than for individual exposure.

The results from observational and aggregated data such as this type of study must be cautiously interpreted. Furthermore, the validity of these findings may be affected by several potential sources of bias, such as units of observation, more confounding factors not included in this study, and the applicability of the statistical techniques. When these informations are available, it will be possible to be more certain about implication of epidemiological studies of air pollution.

In conclusion, these findings showed that the effects of PSI on total mortality rates are likely to be small in magnitude and difficult to detect reliably at this stage.

V. Summary

Multivariate regression analysis was done to examine the relative effects of Pollutant Standards Index (PSI), climatic, and socioeconomic variables on total mortality rates for 23 SMSAs of the United States. Socioeconomic variables explained a greater percentage of the variation in the total mortality rates than did PSI and climatic variables. It is concluded that the effects of PSI on total mortality rates are likely to be small in magnitude and difficult to detect reliably. Some limited conclusions which need further evaluation are discussed.

References

1. L.B. Lave and E.P. Seskin, "An analysis of the association between U.S. mortality and air pollution," J.Am. Statist. Assoc. 68, 284-290, 1973.
2. S.J. Finch and S.C. Morris, "Consistency of Reported Effects of Air Pollution on Mortality" BNL 21808-2, Upton, New York, 1977.
3. M.G. Morgan, S.C. Morris, A.K. Meier, and D.L. Shenk, "A probabilistic meth-

odology for estimating air pollution health effects from coal-fired power plants," Energy Syst. Policy 2, 287-309, 1978.

4. W.F. Hunt, et al., "Guideline for Public Reporting of Daily Air Quality-Pollutant Standards Index (PSI)," U.S. Environmental Protection Agency, EPA 450/2-76-013, 1976.
5. B.G. Ferris, "Health effects of exposure to low levels of regulated air pollutants-A critical review," J. Air Poll. Control Assoc. 28, 482-497, 1978.
6. C.M. Shy, "Epidemiologic evidence and the United States Air Quality Standards," Am. J. Epidemiol. 110, 661-671, 1979.
7. L.B. Lave and E.P. Seskin, "Air Pollution and Human Health," Resources for the Future, Johns Hopkins University Press, Baltimore, 1977.
8. R. Mendelsohn and G. Orcutt, "An empirical analysis of air pollution dose-response curves," J. Environ. Econ. Managmt. 6, 85-106, 1979.
9. H.W. Gottinger, "Air pollution health effects in the Munich Metropolitan Area: Preliminary results based on a statistical model," Environ. Int. 9, 207-220, 1983.
10. P.F. Ricci and R.E. Wyzga, "An overview of cross-sectional studies of mortality and air pollution and related statistical issues," Environ. Int. 9, 177-194, 1983.
11. W.R. Ott, "Concepts of human exposure to air pollution," Environ. Int. 7, 179-196, 1982.
12. J.D. Hackney, W.S. Linn, and E.L. Avol, "Assessing health effects of air pollution," Environ, Sci. Technol. 18, 115A-122A, 1984.
13. U.S. Bureau of the Census, "State and Metropolitan Area Data Book 1979-1980," Washington, D.C., 1982.
14. U.S. Bureau of the Census, "County and City Data Book 1975," Washinton, D.C., 1977.
15. U.S. Bureau of the Census, "Statistical Abstract of the United States 1982-1983," Washington, D.C., 1983.
16. Y.S. Kim, "Air pollution, climate, socioeconomic status and total mortality in the United States," Sci. Tot. Environ. 42, 245-256, 1985.
17. T.W. Anderson and W.H. Riche, "Cold weather and mycardial infarction," Lancet, i, 191, 1970.
18. S.J. States, "Weather and death in Birmingham, Alabama," Environ. Res. 12, 345-350, 1976.
19. A.J. Sadar and M.G. Ruby, "Implementation of the Pollutant Standards Index (PSI)," Abstract for the 77th Annual Meeting of the APCA, 84-67. 8, San Francisco, June 24-29, 1984.

Appendix

A: Names of the SMSA for which data are used

1. Los Angeles-Long Beach, CA
2. Riverside-San Bernardino-Ontario, CA
3. New York, NY-NJ
4. Houston, TX
5. Denver-Boulder, Colo
6. Washington, D.C., Md-Va
7. Philadelphia, Pa-NJ
8. Louisville, Ky-Ind
9. St. Louis, Mo-Ill
10. Portland, Oreg-Wash
11. Salt Lake City-Odgene, Utah
12. Chicago, Ill
13. Kansas City, Ohio-Ky-Ind
14. Seattle-Everett, Wash
15. Cincinnati, Ohio-Ky-Ind
16. Sacramento, CA
17. Buffalo, NY
18. Milwaukee, WI
19. San Francisco-Oakland, CA
20. Tapma=St. Petersburg, Fla
21. Syracuse, NY
22. Rochester, NY
23. San Diego, CA

B: Description of variables selected

Mortality Rates (Deaths per 1,000 population)

TMR: Total mortality rates

Air Quality

PSI: Pollutant Standards Index
(Mean Days by PSI above 100 for one day during one year)

Weather variables

TEMP 1: Mean January Temperature(°F)
TEMP 7: Mean July temperature(°F)
PRECIP: Mean annual precipitation (inch)

Socioeconomic variables

POP DEN: Population density (Persons per square mile)
% ≥ 65: Percentage of area population of 65 years old or more
% UNEMP: Percentage of unemployment