The Spatial Distribution of Perceived Air Quality in Terre Haute, Indiana

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Introduction

A number of researchers have studied possible relationships between air pollution and urban socioeconomic residential patterns. Such studies have not, however, considered air pollution in a perceptual framework. Yet, if air pollution affects urban residential patterns, residents' perceptions of air pollution must somehow be involved. The object of this paper is to present a methodology by which to spatially model air pollution in an urban area such that the model incorporates a human perceptual applicability. The study area is Terre Haute, Indiana, a city that has experienced problems attaining regulatory air pollution levels in recent years.

As part of a study assessing spatial effects of air pollution in Terre Haute, it was necessary to quantify air pollution for locations throughout the city. Two difficulties were inherent to this quantification: (1) Terre Haute does not have a closely-spaced network of air pollution sites and (2) air pollution is actually myriad substances in all three states of matter.

In relation to the latter point, people in Terre Haute perceive air pollution as an entity, and not as a series of unit pollutant components. This has been shown in random interviews with residents (Good, 1978) and agrees with the results of interviews conducted in other cities. Additionally, work has shown that the residents identify "air pollution" almost exclusively with "industrial air pollution". Therefore, in this study it was deemed appropriate to use a single composite value to represent the presence of air pollution at any site using as a base the emissions inventory of Terre Haute's industries. Development of such a value requires mathematical modeling of atmospheric dispersion employing the emissions data to derive city wide concentration of individual pollutants. This permitted derivation of a total pollution value for each industry to use as input to a dispersion model.

A Perceptual Pollution Index

Surrogates—usually sulfur dioxide or particulate matter—have been used to describe intracity pollution patterns. In studying Terre Haute's industrial emission, it was apparent that use of a single pollutant as a surrogate neglected the relative importance of some industries as pollution sources. If, for example, sulfur dioxide had been selected as a single, surrogate pollutant—ostensibly representative of total air pollution—several "dirty", particulate-emitting industries would contribute little to the patterns of air pollution. So, incorporation of all five of the pollutants that are part of the inventory was appropriate.

Indices have long been used in pollution research. Babcock (1970) combined major primary pollutants and oxidant into a total pollution value. This scheme is of note because it weighted pollutants by relative toxicities rather than mass concentrations. Babcock's weighting were based on (then) proposed California air quality standards. Unfortunately, commonly available dispersion models do not consider oxidant-producing synergisms. Walther (1972) used Babcock's work to assess the relative effects of emissions sources. He followed Babcock's reasoning in rating primary pollutants according to the USEPAs National Ambient Air Quality Standards. Tables 1 and 2, respectively, give the Secondary National Ambient Air Quality Standards and the weighting of Babcock and Walther.

TABLE 1. *Secondary National Ambient Air Quality Standards 1971*

Pollutant	*Time Scale*	*Standard*
Carbon Monoxide	1-HR*	40.000
	8-HR*	10.000
Hydrocarbons	3-HR*	.160
Nitrogen Oxides	Annual Arith. Mean	.100
Particulate Matter	24-HR*	.150
	Annual Geom. Mean	.060
Sulfur Oxides	3-HR*	1.300
	24-HR*	.365
	Annual Arith. Mean	.080

* Not to be exceeded more than once per year

24-HR Standards for SO_X and PM have since been deleted

TABLE 2. *Weighting of Pollutants Based on Standards*

Pollutant	*Tolerance Factor*[1]	*Effect Factor*[2]
Carbon Monoxide	5600	1.0
Hydrocarbons	45	125.0
Nitrogen Oxides	250	22.4
Particulate Matter	150	37.3
Sulfur Oxides	260	21.5

[1] From Babcock (1970)

[2] From Walther (1972). Carbon monoxide is used as the reference pollutant and tolerance factors divided into 5600 to obtain effect factors.

The present study used Walthers Effect Factors to create a pollution index. The five major primary pollutants for each Terre Haute industry were weighted according to the Secondary Standards and then summed into an index value. Secondary Standards are based on the best scientific evidence as to the effects of specific pollutants upon the public welfare. Theoretically, the greater the index value, the greater the pollution burden perceived by the public.

The National Ambient Air Quality Standards are not based on odor; but odor is an important part of the public's perception of air pollution. Flesh and others (1974) conducted a national survey of the public and derived a list of odorous industries. This list was used to determine which of Terre Haute's industrial sources were odorous. If an industry was classified as odorous, its index value was doubled. The resulting value was considered a crude approximation of the public's perceptions of relative pollution concentrations. The value derived from the summation was termed the Perceptional Pollution Index value. The general form of the equation is given in Table 3 and an example of its use to derive a Perceptual Pollution Index for a single industry is presented in Table 4.

TABLE 3. *Perceptual Pollution Index Equation*

$$PPI = ((HC \times 125) + (NO_X \times 22.4) + (PM \times 37.3) + (SO_X \times 21.5) + CO) + O.F.$$

WHERE	PPI is the Perceptual Pollution Index number	
	HC are Hydrocarbons	
	NO_X are Nitrogen Oxides	
	PM is particulate matter	
	SO_X are Sulfur Oxides	
	CO is Carbon Monoxide	
AND	O.F. is the odor factor	2 for odorous sources
		1 for nonodorous sources

TABLE 4. *Example of Index for a Single Source*

Malleable Iron Foundry (Classified as an odorous source; O.F. = 2) Data from Vigo County Emissions Inventory:

Pollutant	*Emission Rates (GM/SEC)*
Hydrocarbons	.232
Nitrogen Oxides	3.248
Particulate Matter	.812
Sulfur Oxides	5.394
Carbon Monoxide	.464

Derivation of PPI

$$(((.232 \times 125) + (3.248 \times 22.4) + (.812 \times 37.3) + (5.394 \times 21.5) + .464) \times 2) = 215.037$$

Mapping the Values

A Perceptual Pollution Index value was calculated for each of Terre Haute's industrial sources. These values were used as emission rates in Busse and Zimmerman's Climatological Dispersion Model (1973). In this way, Perceptional Pollution Index values were calculated for each city block in Terre Haute. Using meteorological data from five years, the inputs to the climatological dispersion model were amended for different sets of atmospheric and temporal parameters. Selected results are given in Figures 1, 2 and 3. Figure 1 shows the distribution of Perceptional Pollution Index values for annual conditions in the sections of Terre Haute on the floor of the Wabash Valley. This constriction of study area was made necessary by the fact that simple dispersion modeling is unable to consider significant topographic vari-

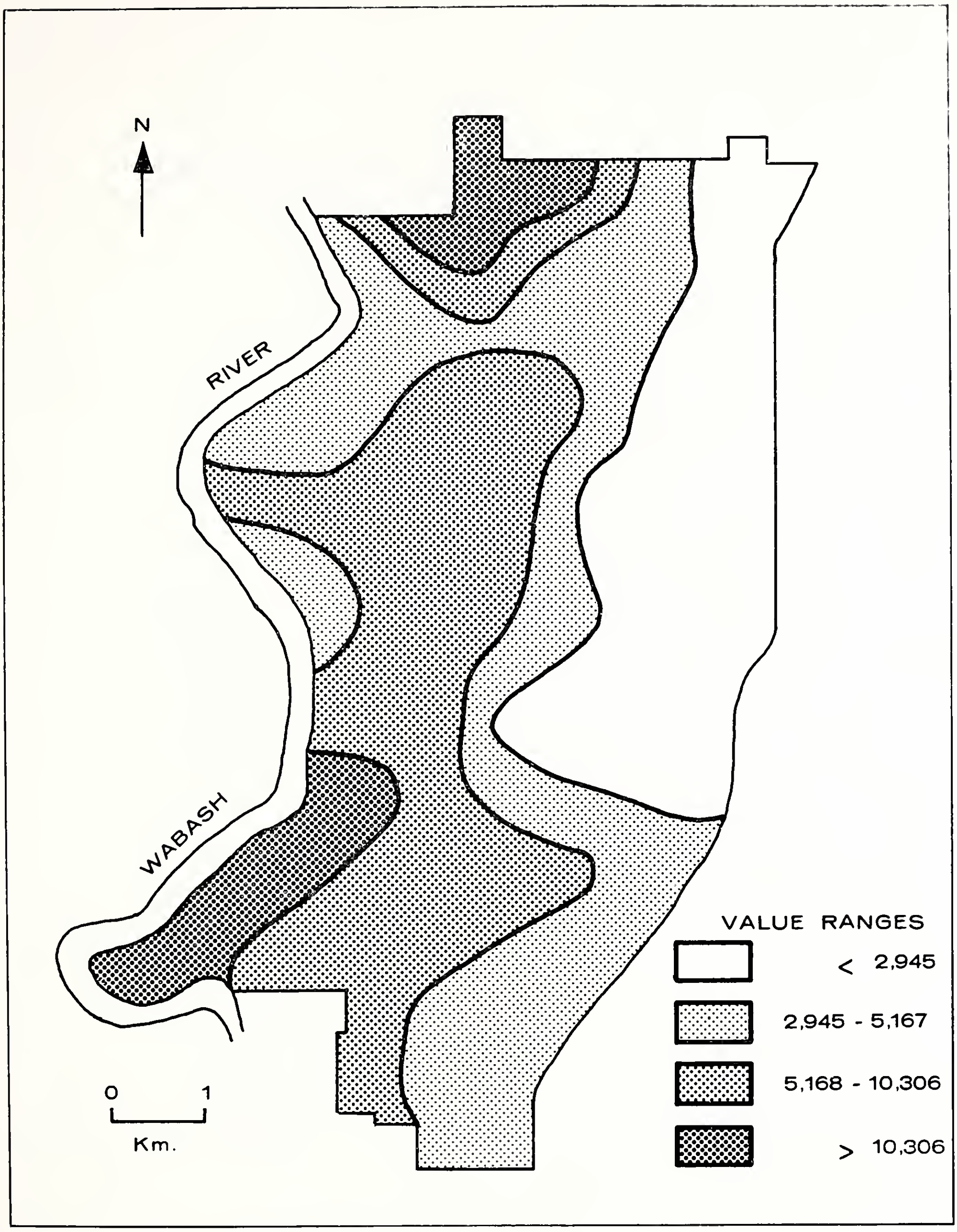

Figure 1. *Perceptual Pollution Index values for annual conditions in Terre Haute, Ind.*

ations. The map, at this scale, does not show the intricacies of the block-by-block patterns derived. It should be noted that Perceptional Pollution Index values represented on the map are on the order of 10^6 times less concentrated than the values used as input. For the annual case, the actual values range from less than 100 to greater than 19000. This range is amenable to correlation with other variables because the index values noticeably vary over horizontal distances on the order of a city block. Maps 2 and 3 indicate striking changes in the pattern of values for south wind and east wind conditions.

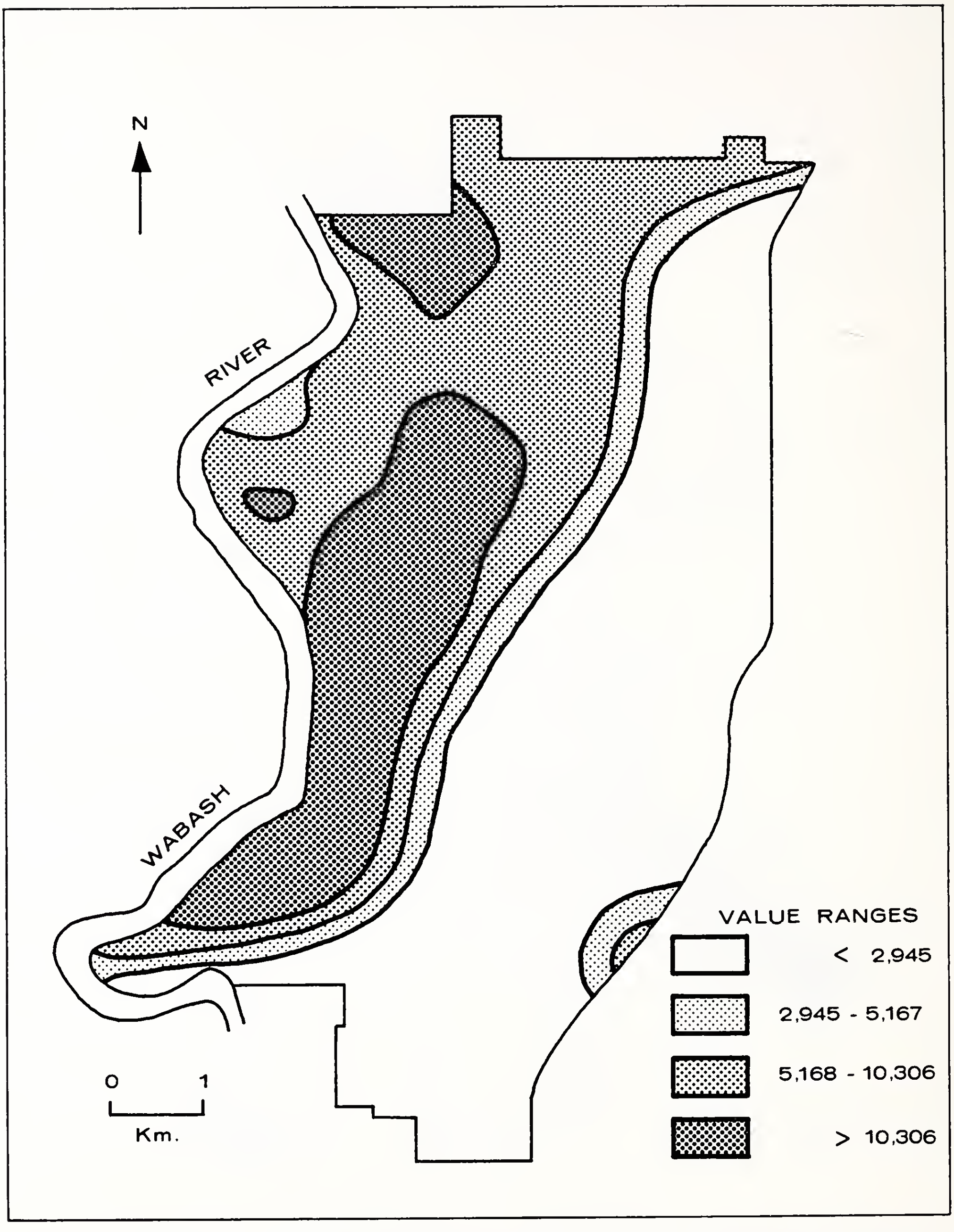

FIGURE 2. *Perceptual Pollution Index values for south wind conditions in Terre Haute, Ind.*

These three maps may be taken as a measure of the perceived air quality. Clearly, air pollution would be most readily observed when meteorological conditions are conducive to higher pollution levels (e.g. as in Figure 2). What is noteworthy, however, are the gradients that occur. Despite the relatively high industrial pollution effluent, perceived air quality varies over a relatively short distance from the source. If air pollution does influence socioeconomic conditions, then areas of perceived pollution as indicated in the maps, should be indicative of the relationship. Such a thesis is currently being tested.

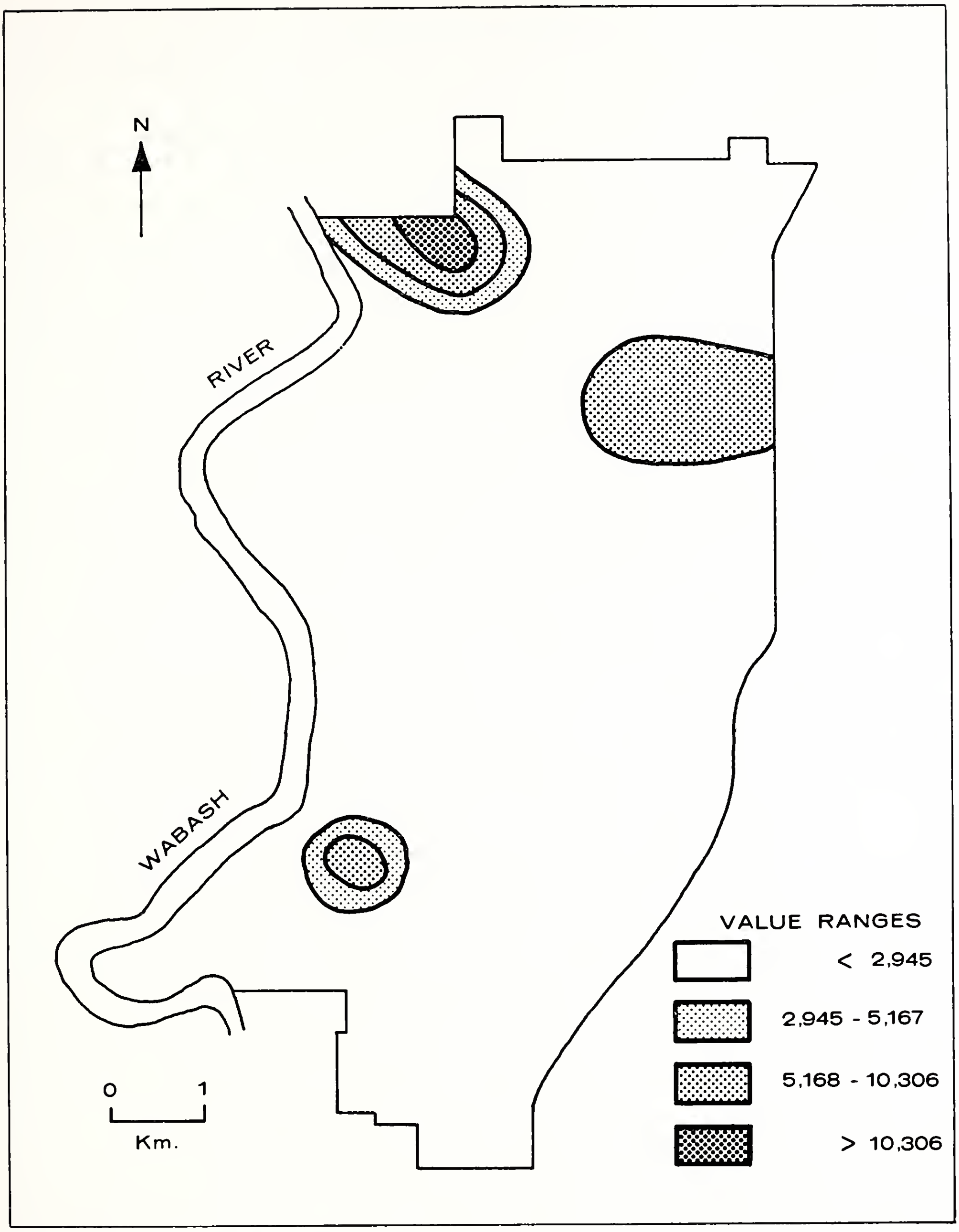

FIGURE 3. *Perceptual Pollution Index values for east wind conditions in Terre Haute, Ind.*

Conclusion

The authors realize that the Perceptional Pollution Index is only a first approximation of the complexities of reality. However, it is desirable to have a complete knowledge of the effects of urban air pollution. This methodology offers the promise of allowing comparison of a total air pollution value with socioeconomic variables. Only then can air pollution control strategies be administered with consistent success. The authors would like to thank the Indiana Academy of Science for financial support for this project.

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