J. ENVIRONMENTAL SYSTEMS, Vol. 21(4) 349-356, 1991-92

MICRO-ENVIRONMENTAL ZONES AND OCCUPANCY FACTORS IN JHARIA COAL-FIELD: PAH HEALTH EXPOSURE ASSESSMENT

J. S. PANDEY

S. PIMPARKAR

P. KHANNA

National Environmental Engineering Research Institute
Nagpur, India

ABSTRACT

An increasingly wide range of toxic chemicals are being continuously released into the environment. Polycyclic aromatic hydrocarbons (PAH) happen to be one of the most hazardous among them because of their carcinogenicity. They are mainly produced by combustion processes involving carbon-based substances such as fossil fuels and biomass, and have been reported to be present in significant concentrations in coal mining and coal processing areas. Responsiveness and susceptibilities to the pollutants, in general, has age-specific variability. A series of recent studies suggest that school children may be both sensitive and specifically reactive to air pollution health effects. Hence, the control of air pollution should be based on the most sensitive groups of persons. In line with pollutant/climate micro-environment concept, human exposures to PAH have been analyzed and estimated (in the present article) in terms of dose rates for residential and industrial micro-environmental zones in Jharia Region. The analysis is based on age-specific breathing rates, body weights, and occupancy factors for different zones.

INTRODUCTION

One of the main objectives of health risk assessment with respect to air pollution is to provide relatively accurate and representative estimates of environmental

doi: 10.2190/QQ5W-1XPJ-UJLH-PJ3G
http://baywood.com

exposures for all study zones, viz. residential, commercial, industrial, etc.This requires a realistic approach for exposure assessment, and involves the following steps:

1. Identification of air pollutants and their sources;
2. Estimation of pollutant concentrations in the surrounding environment; and
3. Assessment of impact of these concentrations on people.

As an alternative to large-scale statistical studies which require an enormous amount of data, analysts generally attempt to derive dose—response relationships on the basis of laboratory studies on animals or from clinical data available for human beings. Epidemiological studies dealing with the effects of air pollutants on human health [1, 2] have remained endowed with a large amount of uncertainties and consequent controversies mainly arising out of the following factors:

1. Validity of air quality data for computing current exposures of the individuals residing in that area;
2. Validity of current exposures as a measure of the long-term exposure history relevant to explaining chronic effects and mortality; and
3. Functionalities interlinking dose and response.

The range of gaseous air pollutants arising from different sources is usually classified as shown in Table 1 [3], with the primary pollutants arising directly from the source and the secondary pollutants being formed in the atmosphere from the precursor gases emitted [1].

CARCINOGENS IN THE ENVIRONMENT [4]

Several hundred exogenous agents—physical, chemical, and biological—have been identified as capable of producing cancer in animals. For many of these agents, there is direct evidence of carcinogenicity in humans, derived from epidemiological observations of exposed groups. There is sound evidence to support the idea that exposure to exogenous agents, whether precisely identified or only suspected, is a necessary determinant for the majority of cancers occurring today in developed countries. These exogenous agents, acting individually or in combination, include tobacco, alcohol, dietary components, reproduction and sexual behavior, occupational exposures, and pollutants in air, water, and soil.

Several carcinogens are present in the general environment and, in particular, in the ambient air. The main group consists of polycyclic aromatic hydrocarbons (PAH), derived from incomplete combustion of fossil fuels (used in domestic heating, industrial plants, and gasoline and diesel engines) which release both particulate and vapor-phase emissions in the atmosphere. These emissions contain, along with other compounds, both PAH and condensed-ring molecules with atoms other than carbon and hydrogen: collectively these and PAH are referred to as polycyclic organic matter (POM). Other carcinogenic pollutants often detected in the general ambient air, although usually in minute amounts, include asbestos, radon, arsenic, and

Table 1. Classification of Gaseous Air Pollutants

Class	Primary Pollutants	Secondary Pollutants	Man-Made Source
1. Sulfur-containing compounds	Sulfur dioxide (SO_2) Hydrogen sulfide (H_2S)	Sulfuric acid (H_2SO_4) Sulfates	Combustion of sulfur containing fuels
2. Nitrogen-containing compounds	Nitric oxide (NO) Ammonia (NH_3)	Nitrogen dioxide (NO_2) Nitrates	Reaction of nitrogen and oxygen at high temperature
3. Carbon-containing compounds; halogen compounds	Chlorofluoro-carbon (CFCs) Hydrogen fluoride (HF) Chlorine (Cl_2) Polycyclic Aromatic Hydrocarbons (PAH)	Aldehydes, Ketones	Combustion of fuels; petroleum refining; solvent use; aerosol sprays
4. Oxides of carbon	Carbon monoxide (CO) Carbon dioxide (CO_2)	None	Combustion

Source: Seinfeld [3].

nitrosamines. Synergistic effects result in more pronounced carcinogenicity. Sulfur dioxide in combination with benzo (a) pyrene, a polycyclic hydrocarbon, has been reported to have produced lung tumors in animals chronically exposed.

AGE SPECIFIC HEALTH EFFECTS [5]

Natural variability in responsiveness to air pollution is observed in all populations. Generally speaking, susceptibility is great among premature infants, in newborn, the elderly, and the infirm. Those with chronic diseases of the lungs or heart are thought to be at particular risk. Because of the wide variation in sensitivity to air pollution of different groups in the population, data concerning health effects on healthy persons may not be as important as the responses of the individuals most likely to be sensitive. A series of recent studies suggest that school children may be both sensitive and specifically reactive to air pollution health effects. The control of air pollution, to the extent that it is based on health effects, should be based on the most sensitive groups of persons. This principle requires that these sensitive groups be definable in terms of age and/or medical status.

PAH-CONCENTRATIONS IN JHARIA COAL-FIELDS

Polycyclic Aromatic Hydrocarbons (PAH) compounds have been found to be present in the industrial and urban atmospheres and are more likely to be present in coal mining and coal processing areas. Concentration ranges of benzo (a) anthracene, benzo (a) pyrene, and perylene in airborne particles of Jharia coal-fields collected during winter months (November through March) are presented in Table 2.

ANALYSIS METHODOLOGY

In the present article, human exposures to PAH have been analyzed and estimated in terms of dose rates for residential and industrial zones. The analysis is based on age-specific breathing rates, body weights, and occupancy factors for different zones.

An individual's exposure to a contaminant is defined as the contact at one or more boundaries (e.g., mouth and skin) between a human being and a contaminant at a specific concentration for a period of time. Total exposure includes contributions from all media (soil, water, food, air, plants) that contain a contaminant and all pathways of entry (inhalation, ingestion, dermal).

Mathematically, exposure is defined as:

$$E = \int_{t1}^{t2} C(t)\, dt, \tag{1}$$

where,

E = exposure; and
C(t) = concentration which varies as a function of time.

The dose rate is estimated as:

$$D = (Br/Bw) \int_{0}^{24} C(t) \times Of(t)\, dt, \tag{2}$$

Table 2. Concentration Ragnes of Benzo (a) Anthracene, Benzo (a) Pyrene, and Perylene in Airborne Particulates of Jharia Coal-field Collected During Winter Months (November through March), 1977-80 (Sampling Period: 24 Hours)

Types of Sampling Area	Number of Samples	Concentration (ug/g of Particulate Matter)		
		Benzo (a) Anthracene	Benzo (a) Pyrene	Perylene
Residential	3	18.5 – 26.8	9.6 – 19.6	Trace – 4.9
Industrial	20	168 – 386	81.0 – 271	2.5 – 17.7

SOURCE: Mukherjee *et al.* [6].

where,

Br = breathing rate (age specific);
Bw = body weight (age specific);
Of(t) = occupancy factor (zone specific);
a = adults;
c = children; and
i = infants.

Unit pathway dose factor f(a,c,i) is defined as dose factor per unit concentration of the pollutant. The lifetime equivalent daily dose-rate is calculated by taking the weighted sum as follows:

$$F_i = I \times f(\text{infant}) + C \times f(\text{child}) + A \times f(\text{adult})\,, \tag{3}$$

where,

I = 2/70;
C = 14/70; and
A = 54/70.

RESULTS

Dose rates have been computed for adults, children, and infants. Adults, children, and infants have been defined as those belonging to age group sixteen to seventy, age group two to sixteen, and age group newborn to two, respectively. Table 3 presents body weight and breathing rates for adults, children, and infants. Occupancy factors for residential and industrial zones have been depicted in Figures 1 and 2.

Table 3. Body Weight and Breathing Rates

Description	Symbol	Value
1. Adults (16-70 years)		
Body weight	BWa	67 Kg
Breathing rate (av)	BRa	14.7 (L/min.)
2. Children (2-16 years)		
Body weight	BWc	32 Kg
Breathing rate (av)	BRc	10.3 (L/min.)
3. Infants (0-2 years)		
Body weight	BWi	8.5 Kg
Breathing rate (av)	BRi	1.8 (L/min.)

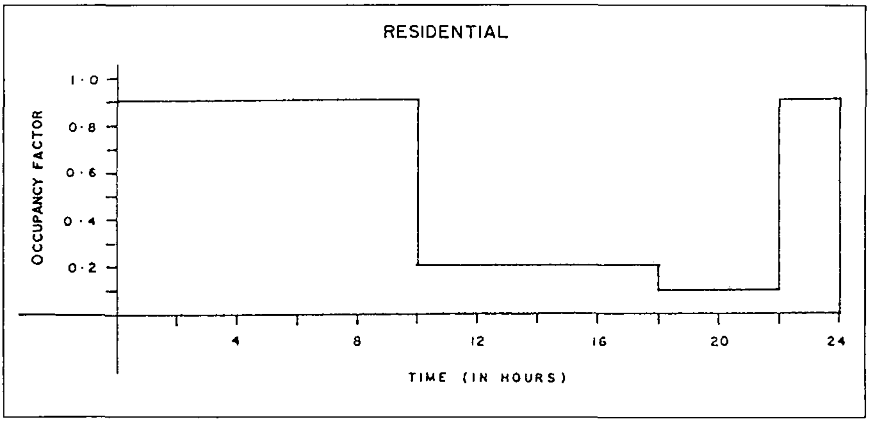

Figure 1. Probability of exposure in residential area.

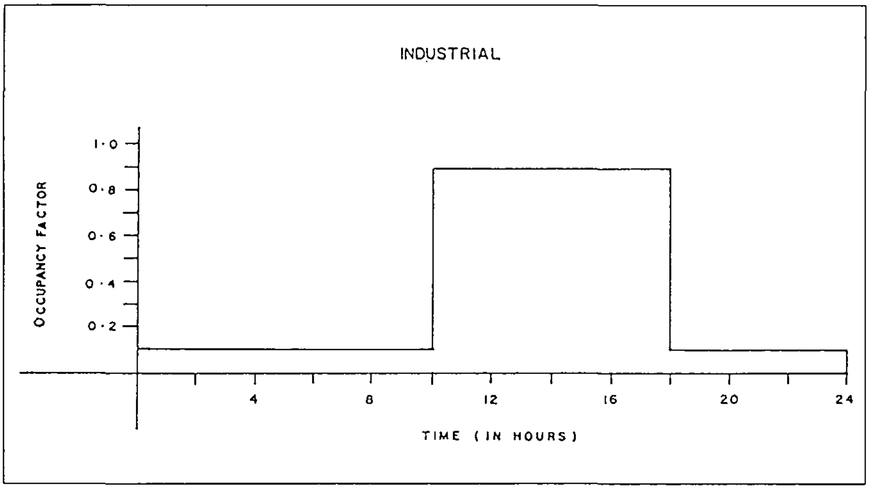

Figure 2. Probability of exposure in industrial area.

Figures 3 and 4 present doses for different age groups (Da, Dc, Di) with respect to benzo (a) anthracene, benzo (a) pyrene, and perylene. In residential zones, highest dose for any age group is contributed by benzo (a) anthracene. The lowest doses are due to perylene. The life-time equivalent daily dose rate is highest (Figure 3) for benzo (a) anthracene (2.7×10^{-5}) and lowest for perylene (6×10^{-6}).

In the industrial area, results are quire different. The highest doses are observed due to benzo (a) pyrene. Dose is maximum in case of infants (9.96×10^{-4}). The

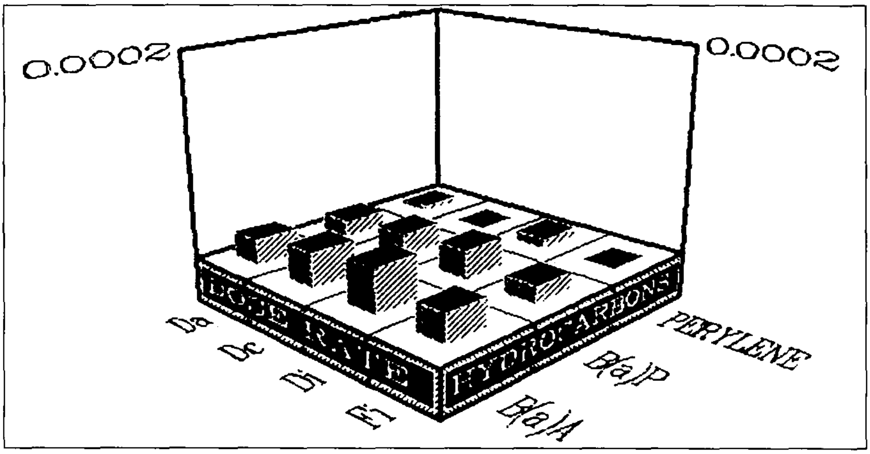

Figure 3. PAH effect on residential area.

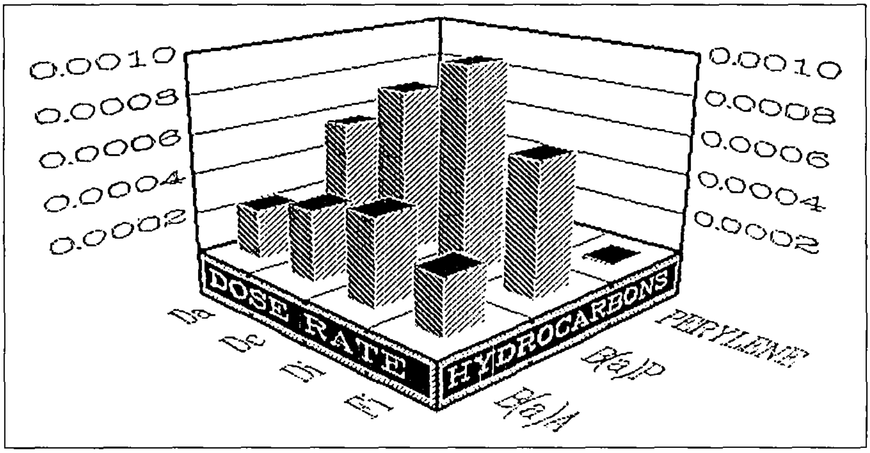

Figure 4. PAH effect on industrial area.

life-time equivalent daily dose rate is the highest (6.38×10^{-4}) for benzo (a) pyrene. Dose rates are lowest (Figure 4) for adults.

DISCUSSION

On the basis of preceding analysis, use of the concept of the pollutant/climate "micro-environment" is advocated. This concept has been used earlier also for dividing the macro-environment into more homogeneous components in which concentrations of specific air pollutants can be more easily estimated from known characteristics of these micro-environments [7]. The micro-environments considered in the present case are residential and industrial zones. The present work, notwithstanding the several simplified assumptions involved, is intended to provide a theoretical framework upon which more realistic and precise toxicokinetic and pharmacodynamic models can be developed.

REFERENCES

1 R. Simpson, Health Impact Assessment: Some Problems in Air Pollution Management, *Environmental Impact Assessment Review, 10*, pp. 157-163, 1990.
2. A. M. Freeman, The Health Implications of Residual Discharges: A Methodological Overview, in *Explorations in Natural Resource Economics*, V. K. Smith and J. V. Krutilla (eds.), Johns Hopkins University Press, Baltimore, Maryland, 1982.
3. J. H. Seinfeld, *Air Pollution*, McGraw-Hill, New York, 1974.
4. M. J. Suess, K. Grefen, and D. W. Reinisch (eds.), *Ambient Air Pollutants from Industrial Sources*, Elsevier Science Publishers, 1985.
5. J. R. Goldsmith, Effect of Air Pollution on Human Health, in *Air Pollution, Vol. 1*, A. C. Stern (ed.), Academic Press, New York/London, 1968.
6. A. K. Mukherjee and M. K. Chakraborty, A Suitable Method for Analysis of Some Polycyclic Aromatic Hydrocarbons in Air-Borne Particulate Matter, *Indian Journal of Environmental Health, 31*:1, pp. 1-7, 1989.
7. M. Fugas, Assessment of Total Exposure to an Air Pollutant, in *Proceedings of the International Conference on Environmental Sensing and Assessment, II*:Paper 38-5, Institute of Electrical and Electronics Engineering, Inc., New York, 1976.

Direct reprint requests to:

Dr. J. S. Pandey
Computer Applications Division
NEERI
Nehru Marg
Nagpur 440 020, India