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Environmental Carcinogens and Human Cancer: Estimation of Exposure to Carcinogens in the Ambient Air

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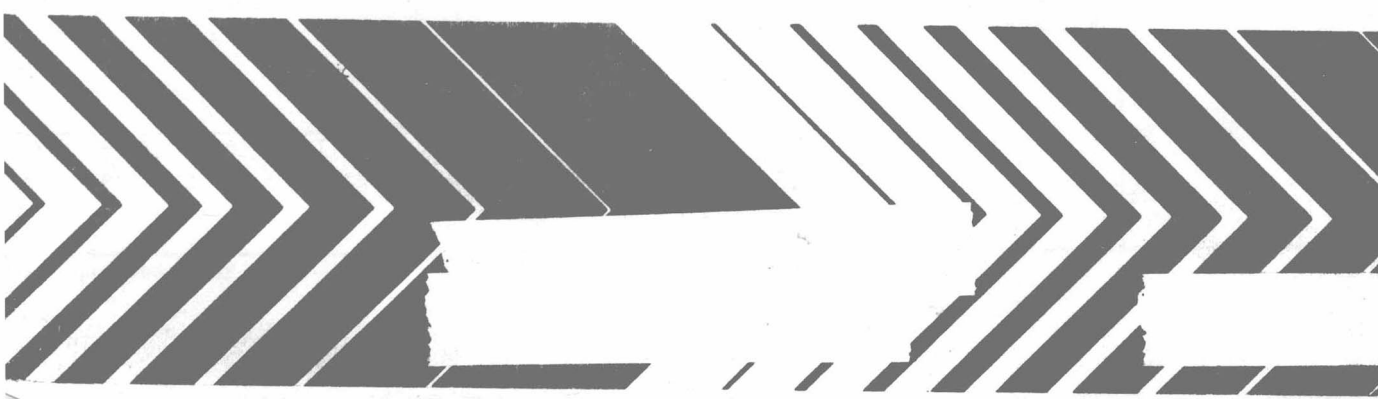

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ENVIRONMENTAL CARCINOGENS AND HUMAN CANCER

Estimation of Exposure to Carcinogens in the Ambient Air

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FOREWORD

The many benefits of our modern, developing, industrial society are accompanied by certain hazards. Careful assessment of the relative risk of existing and new man-made environmental hazards is necessary for the establishment of sound regulatory policy. These regulations serve to enhance the quality of our environment in order to promote the public health and welfare and the productive capacity of our Nation's population.

The Health Effects Research Laboratory, Research Triangle Park, conducts a coordinated environmental health research program in toxicology, epidemiology, and clinical studies using human volunteer subjects. These studies address problems in air pollution, non-ionizing radiation, environmental carcinogenesis and the toxicology of pesticides as well as other chemical pollutants. The Laboratory participates in the development and revision of air quality criteria documents on pollutants for which national ambient air quality standards exist or are proposed, provides the data for registration of new pesticides or proposed suspension of those already in use, conducts research on hazardous and toxic materials, and is primarily responsible for providing the health basis for non-ionizing radiation standards. Direct support to the regulatory function of the Agency is provided in the form of expert testimony and preparation of affidavits as well as expert advice to the Administrator to assure the adequacy of health care and surveillance of persons having suffered imminent and substantial endangerment of their health.

This report is one of a series under the main title Environmental Carcinogens and Human Cancer. A broad range of objectives directed to the quantitative assessment of the relationship between environmental exposure to carcinogens and increased risk of cancer were addressed. Particular attention was given to development of methodologies and appropriate data bases as well as to identification of community populations for study of specific carcinogen-cancer associations. The series of reports documents the methodologies, resource data, and findings resulting from project activities.

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ABSTRACT

In this study, a methodology for ambient exposure analysis of carcinogens was developed based on a pilot study of the Detroit Metropolitan area. The specific aim of the analysis was to identify high and low exposure areas within the study area. Four known or suspected carcinogens and groups of carcinogens: BaP, trichloroethylene, nickel and its compounds, and cadmium and its compounds were studied. The analysis of ambient exposure to BaP consisted of the use of the Air Quality Display Model (AQDM) to simulate levels of BaP which might have existed during 1956 to 1960. The analysis for BaP involved a multistep procedure. In order to examine the accuracy of AQDM predicted BaP ambient concentrations, present conditions (1975-1976) were simulated and compared against known concentrations in the area. Next, BaP emissions for the period 1956-1960 were estimated by analyzing past trends for significant sources. This emissions data base, along with meteorological data for the same period, was used as an input to AQDM to predict historical exposure to BaP. The analysis for the other three carcinogens was less detailed than that for BaP. It was comprised of estimation of emissions and calculation of emission density for each of the three carcinogens. For nickel and cadmium, it also included a comparison of spatial variation in emissions with measured air quality patterns in the Detroit area. The results of this study were very encouraging in light of the scarcity of data on carcinogens. Excellent correlation between observed and estimated concentrations was obtained for BaP. In the case of nickel and cadmium, the estimation between observed and estimated concentrations was obtained for BaP. In the case of nickel and cadmium, the estimated emission density patters matched well with observed air quality patterns. Due to the lack of data on ambient concentrations, a similar comparison was not possible for trichloroethylene. The carcinogen exposure patterns developed in this study are being used in the selection of population samples for an epidemiological study of the area.

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SECTION 1

INTRODUCTION

In order to investigate the association between exposure to a carcinogen present in the ambient air and incidence of cancer, high and low carcinogen exposure areas need to be identified. Human carcinogenesis generally has a long latency period--spanning 5 to 40 years. Such a latency period implies that identification of current high and low exposure areas is not sufficient in itself; historical trends in spatial variations must be examined. Estimation of historical exposure to a carcinogen is possible if monitoring data on the carcinogen are available for several sites for a period of years. It is recognized that sufficient information on ambient concentrations to depict historical and spatial variations is not available for any of the 23 carcinogens or group of carcinogens selected for this study (Table 1). The objective of this study was to develop and apply alternative approaches for characterization of carcinogen exposure.

Based on a pilot study of one area, a methodology for first generation ambient air exposure analysis of carcinogens was developed. The specific aim of the exposure analysis was to identify high and low exposure areas within a multicounty study area. This report gives a rationale and technical approach for the methodology used and describes results for the first pilot study area--Detroit metropolitan area.

The summary and conclusions of ambient exposure analysis for the Detroit metropolitan area are presented in the next section. A detailed discussion of the rationale and technical approach for characterization of ambient exposure to carcinogens appears in Section 3. Using this approach, exposures to various carcinogens prevalent in the ambient atmosphere of selected study areas were estimated and analyzed. Section 4 describes available data bases, specific approaches, and results for each carcinogen included for exposure analysis in the Detroit pilot study area.

The results of the carcinogen exposure analysis performed in this task, in the form of spatial gradation or differences in ambient concentrations, are used to support an epidemiologic study. In order to examine the degree of association between high carcinogen exposure and increased cancer risk, samples of cancer victims and matched control groups are selected from both high and low exposure areas. The details of this primary data collection and its analysis will be reported as the epidemiologic study is completed.

TABLE 1. RANKED LIST OF CHEMICALS WITH CARCINOGENIC POTENTIAL*

Priority Group	Number†	Chemical Name
I		
Known or suspected human carcinogens	1	Benzene
	2	Vinyl chloride monomer
	3	Acrylonitrile
	4	Nickel and its compounds (primarily nickel carbonyl and nickel subsulfide)
	5	Ethylene dibromide
	6	Asbestos
	7	Chromium and its compounds (primarily calcium chromate)
	8	Benzo-a-pyrene (BaP)
	9	Arsenic trioxide
	10	Benzidine
II	11	Ethylene oxide
Carcinogenic to laboratory animals	12	Carbon tetrachloride
	13	Trichloroethylene
	14	Chloroform
	15	Vinylidene chloride
	16	Cadmium and its compounds
	17	Dimethyl sulfate
	18	Chloromethyl methyl ether (along with bischloromethyl ether)
III	19	Formaldehyde
Carcinogenicity not confirmed or chemical is no longer produced	20	Tetraethyl lead
	21	Pentachlorophenol (PCP)
	22	Polychlorinated biphenyl (PCB)
	23	Beryllium and its compounds

* Reference 1.

† Ranked within priority group of U.S. production.

SECTION 2

SUMMARY AND CONCLUSIONS

Due to the generally perceived lack of information on the sources of carcinogenic substances, their emissions and their concentrations in the air, ambient exposure analysis would seem impossible at the present time. This is no doubt true for many carcinogens for which there is little or no information on emissions or ambient concentrations. However, for some carcinogens piecemeal information related to emissions and air quality exists. An attempt has been made in this task to show that various pieces of information can be integrated to obtain some understanding of differences in ambient exposures to carcinogens on a subregional basis.

Candidate pollutants for exposure analysis for the Detroit study areas were chosen based on their carcinogenic risk and feasibility of analysis. Benzo-a-pyrene (BaP) offered the most promise; it had one of the most comprehensive sets of emission factors of the 23 carcinogens selected in this study. Similarly, some historical air quality data were available for BaP in the Detroit area. The exposure analysis for BaP consisted of air quality modeling with a routinely used multisource model to simulate present (represented by 1975-76) and past (1956-60) ambient concentrations in the study area. The 1975-76 conditions were simulated to check accuracy of prediction by estimating concentrations at BaP monitoring sites. The agreement between observed and predicted BaP concentrations was excellent; $R^2 = 0.98$. The 1956-60 concentrations were estimated to assess past exposures. Past emissions were estimated by analyzing trends for significant sources. The air quality information for the period 1956-60 was very limited; only 12 monthly observations were available for one site during 1958-59. No statistical analysis was possible, but for the one site for which data were available, the observed and predicted concentrations were close (observed, 15.0 ng/m^3; predicted, 14.1 ng/m^3). Based on the 1956-60 simulation, high and low BaP exposure areas were identified (see Figure 17, page 66).

Three other carcinogens--nickel,* cadmium,* and trichloroethylene--were also analyzed for the Detroit study area. However, in these cases, the data were inadequate for an extensive analysis. Simulation of the atmospheric diffusion process was not included and only 1976 emission density and air quality profiles were examined. For nickel and cadmium, crude air quality patterns developed based on limited data matched well with emissions profiles. Since emissions and air quality patterns are based on two independent data bases, the agreement was impressive. The

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* Certain metal-containing compounds are identified as carcinogens. However, due to a lack of data on specific compounds, the analysis and discussion included in this report refers only to metals in their elemental form.

high/low exposure areas for nickel and cadmium will be shown in Figures 26 and 31, respectively. In the case of trichloroethylene, no air quality data were available and uncertainty exists about its behavior in the atmosphere. Consequently, only limited confidence can be attached to its high/low exposure characterization which is solely based on emissions data (see Figure 21, page 72).

It has been demonstrated in this task that a first generation characterization of ambient exposure is possible for a limited number of carcinogens, primarily, trace metals and combustion products such as BaP. For most organic chemicals very limited information on emissions and virtually no air quality concentration data are available. As information on source emissions and ambient concentrations becomes available, it should be possible to characterize ambient exposures to these chemicals.

SECTION 3

TECHNICAL APPROACH

RATIONALE

The objective of this study was to estimate variations in ambient exposure to carcinogens within an area consisting of a few counties. A detailed exposure analysis requires information on time-varying ambient concentrations at several locations which are spatially representative. For more precise estimates of exposure, factors such as indoor-outdoor concentration differentials, occupational exposure, etc., need to be addressed. However, these were not within the scope of the present study.

The extent of information which describes existing levels of carcinogens varies from data on ambient concentrations at a few sites in an area to no air quality data at all. Even when the ambient air quality data are available, these are seldom sufficient to describe spatial variations. Historical data which can describe past air quality are even more scarce. For most carcinogens there is little information available on past ambient concentrations. Ambient air quality has been monitored for a few carcinogens but generally it has been limited to one or two locations in any given region. Consequently, air quality information alone cannot describe spatial or historic changes in ambient exposure to carcinogens, and there was a need to develop another method for determining high and low exposure areas.

Exposures could be estimated by air quality models which calculate concentrations at designated locations by simulating an atmospheric diffusion process in the area under consideration. Primary input to these models comprises information on emission sources and meteorological conditions. Due to uncertainties in the actual diffusion process and limited emission and meteorological data, results of the model calculations have to be checked or calibrated against measured concentrations for a period which is compatible with the input data. Historical trends in spatial distribution of ambient concentrations could be established if the air quality model predicts present conditions fairly well, and if there is some information on past air quality at one or more locations. For estimating historical emissions, significant emission sources need to be identified and trends in process parameters relating to those sources have to be examined. Similarly, the extent of emission control in the past has to be considered.

The modeling approach may not be justifiable if the input data are insufficient and no air quality information exists. In such cases, a simpler analysis such as plotting of emission density would be preferable. Emission density is determined by computing emissions per unit