Measuring the effects of air pollution on the morbidity, mortality and healthcare consumption of the population in the southern region of Israel

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Part B – Abstract

Background

Air pollution is recognized as a growing health hazard worldwide. Previous studies have demonstrated a positive correlation between ambient air pollution levels and emergency room visits, and a higher prevalence of respiratory symptoms among children exposed to air pollutants. Many of these studies, however, explored the health effects of pollution among children but not adults, and examined only a limited range of health outcomes. Furthermore, many were carried out over a decade ago, when the overall air pollution burden was lower, and the technology necessary for measuring various pollutants was not available.

Study objectives

Geographic mapping component:

1. To geographically model and map the dispersal of pollution particles.
2. To identify "pollution hotspots" under various meteorological conditions

Health outcome component:

1. To measure the impact of pollution episodes on hospital referrals, admissions and deaths.
2. To measure the impact of pollution episodes on referrals to community healthcare clinics.
3. To establish health-outcome-driven emissions thresholds.

Economic consequences component:

1. To estimate the costs of treating the effects of air pollution episodes.
2. To evaluate the cost-benefit ratio of post-event treatment of patients, to the alternative strategy of investment in pollution abatement technologies.

Methods

The geographic mapping component of the proposed study will be carried out using geographic information system (GIS) modelling. Continuous air quality data are available from 18 sampling stations in the Ashkelon District area for the period between January 1995 and December 2004. A dynamic dispersal model will be constructed to describe the directional behavior and geographical gradients of pollutants under various meteorological conditions. The health outcomes component will be executed using a historical-prospective cohort study design to describe the association between air pollution episodes and diagnosis-specific hospitalizations, diagnosis-specific clinic

visits, use of selected medications and attributable deaths. The economic consequences component will employ spreadsheet modelling to calculate the cost to the medical care system and to the economy of treating the short-term health effects of pollution episodes. A cost-benefit analysis will explore the potential for cost savings through a national strategy of investment in pollution abatement technologies.

Part C (1) – Detailed study plan

1. Background

1A. Introduction

Air pollution is recognized worldwide as a major population health hazard. Several leading pollutants have been linked to adverse health outcomes. Sulfur dioxide (SO_2) is a pollutant that arises from the combustion of sulfur-containing fuels such as coal and oil. In developed countries, emissions of SO_2 originate predominantly from major point sources such as power stations that burn coal or oil, industrial combustion plants, and sulfuric acid works. [1] Oxides of nitrogen (NO_x) are the result of high-temperature combustion, and are present in two major forms: nitric oxide (NO) and nitrogen dioxide (NO_2). NO_x are ubiquitous urban air pollutants whose main sources include exhaust of benzene and diesel motor engines, boilers fired by coal, oil and gas such as power stations, and industrial processes that produce NO. A third major group of pollutants are airborne particles of various sizes, not all of which are associated with adverse health effects. Inhalable particles less than 10 μm in diameter (PM_{10}) include the majority of atmospheric particles, excluding the upper range of coarse particles which are believed to be of little health significance. Smaller particles, which are not only inhaled but which can also penetrate into the alveolar region of the lung, are designated $PM_{2.5}$. Ozone (O_3) is a pollutant which differs from the others in that it is secondary in origin rather than being emitted directly by a primary source. Ozone is the product of a photochemical reaction wherein sunlight converts the oxygen components of NO_x into O_3 in the presence of volatile organic compounds such as hydrocarbons.

The different pollutants have various effects on the human respiratory system. Acute episodes in which particulates and acid aerosols are at high levels increase mortality from respiratory disease in all age groups. [2] Exposure to 10 parts-per-million (ppm) of SO_2 results in irritation of the eyes, throat and mucous membranes, while exposure concentrations as low as 0.25-0.5 ppm results in bronchoconstriction, wheezing and shortness of breath among asthmatics, especially when accompanied by moderate exercise. [3,4] Inhalation of ozone has been shown to cause lung inflammation, acute decrease in lung function and exacerbation of asthma. Large studies of hospital admission data have shown a significant association between O_3 levels and hospital admissions for acute respiratory disease, [2] and several studies have shown a significant association between exposure to elevated ambient O_3 levels and emergency room visits for asthma. [5-7] In addition to these short-term effects, at least one study has indicated a possible association between lifetime ozone exposure and a significant reduction in terminal airflow velocity. [8] Controlled human exposure to NO_2 has been shown to result in increased levels of inflammatory mediators and changes in cell counts and distributions in the lung after short exposures to levels as low as 1 mg/m^3. [9,10] Evidence validated in studies conducted in over 30 populations has established an association between PM_{10} particles and adverse health effects. Furthermore, PM_{10} levels have been shown to be associated with hospital admissions for respiratory disease, aggravation of asthma, increased school absence and lower lung function in children. There is evidence that these associations are stronger if $PM_{2.5}$ is considered instead of PM_{10}. [2]

Several methodological approaches can be taken in measuring the adverse health effects of air pollution, one of which is the investigation of air pollution episodes. Under this approach, increases in measures of morbidity and mortality are temporally associated with the occurrence of a pollution episode. Direct measures of morbidity include specific symptoms relevant to air pollution, such as eye and respiratory tract irritation, the use of certain medications, and reductions in lung function. Data on the use of medical services are a readily-available source of information on morbidity, including emergency department visits, hospital admissions, community clinic visits, and pharmacy data.

1B. Air pollution in Israel

Several studies on the health effects of air pollution have been conducted in Israel. Areas that have drawn special attention include the Haifa-Krayot area, home to several petrochemical factories and oil refineries [11,12]; the Hadera District, home to a large coal-burning power plant; the greater Tel Aviv-Gush Dan area, which experiences a large volume of daily motor vehicle traffic [13,14]; and the Ashkelon District, home to coal- oil- and gas-burning power stations, oil refineries and additional heavy industries. [15] Several of these studies, including one that employed the novel use of artificial neural networks to predict the effects of pollution on health, found correlations between ambient air pollution levels and emergency room visits among children and adults [14,15], and found a higher prevalence of respiratory symptoms among children exposed to air pollutants [12]. Most of these studies, however, have concentrated on the effects in children, and have looked at a limited range of health outcomes. Air pollution in Israel and its effects on health are far from being understood, and the role of air pollution on respiratory health remains unclear [16]. As recently as 2002, the Israeli Public Health Service and the Ministry of Health's Department of Environmental Epidemiology cited air pollution as an increasing problem in Israel, and called publicly for "an intensification of applied research in this field in Israel, in order to establish a better data platform required for defining the national health policy in this field." [17]

2. Relevance to 2004 Call for Proposals

This proposal comes in direct response to the current Ministry of Science and Technology Call for Proposals, which lists Health and the Environment as a preferred topic for applied research. The Ministry's guidelines specifically stress a preference for studies linking morbidity and mortality to environmental factors such as air pollution. The proposed study meets this definition directly, and further seeks to directly link air pollution episodes to increases in morbidity, mortality and utilization of health services.

3. Innovation of the proposed study

To our knowledge, no study of air pollution of comparable breadth and depth has been undertaken in Israel, and an extensive review of the published literature shows that our proposed study design is a novel approach to the subject. The proposed multidisciplinary three-year study design combines several important attributes missing from previous studies. First, while previous local studies were cross-sectional in design [12,18] or covered a short study period ranging from 3 months to 4 years, [14,15,19], the proposed study will include a longitudinal historic-cohort component spanning 10 years of followup between 1995-2004. Second, most studies in Israel have measured health outcomes largely in children. While it is recognized that children may be especially susceptible to the effects of air pollution, the scope and impact of health outcomes in adults remains largely unstudied. The health effects on adults are especially important among high-risk populations, such as those with heart disease, chronic lung disease, renal insufficiency and the immune deficient. Third, nearly all of the Israeli air pollution data have been collected in studies that were carried out over a decade ago, when the overall air pollution burden may have been lower, and the technology necessary for measuring various pollutants such as O_3 and $PM_{2.5}$ were not always available [11,12,14,15,18,19].

In addition to these stated advantages over previous research, we propose to study components of air pollution which have not received attention in Israel to date. No published studies have addressed the mapping of pollutant dispersal in the study region, and we are aware of no studies of the direct and indirect health costs of air pollution.

4. Multilateral cooperation for the proposed study

The multilateral working group SISPAQ (Southern Israel Scientific Partnership on Air Quality) has been formed for the purpose of conducting the proposed study, in direct response to the current Call for Proposals, which stresses a preference for inter-organizational research. Partners in SISPAQ include representatives of Clalit Health Services, Maccabi Health Services, the Ashkelon Union of Towns for Environmental Protection (UTEP), the Ashdod UTEP, the Ashkelon District Health Office (DHO) and the Barzilai Medical Center (BMC) Research Institute. The study will be centrally coordinated and directed by the principal investigators at BMC, but representatives of all the partner organizations will cooperate in the various stages of the study efforts. All partners have been involved in designing the overall study framework. The Ashkelon and Ashdod UTEPs will provide exposure data in the form of pollutant measurements at 18 air sampling stations over the 10-year study period. BMC, Clalit and Maccabi Health Services will provide outcome data on the demand for various forms of primary, secondary and tertiary medical care on a daily basis over the entire 10-year study period, and will contribute to the economic modelling component. The Ashkelon DHO will provide data on mortality, and together with BMC will conduct geographic information system (GIS) modelling of air pollution dispersal patterns.

5. Significance of the proposed study

Air pollution is a growing concern among the the Israeli population, evidenced by a growing public awareness to the topic and increasing pressure by the public on responsible authorities at all levels to take a more proactive approach to protecting the public health against potential adverse effects of environmental pollution of all types. However, intensified study of the health effects of air pollution are necessary in order to enable authorities to make well-informed, evidence-based public health policy decisions. The present study's results will provide several important utilities for direct implementation by the general public, medical researchers and regulatory authorities in Israel and abroad. The proposed study is designed to identify levels and patterns of pollution associated with a detectable impact on public health, which will enable the establishment of health-outcome-driven emissions standards. The findings of the study will provide evidence-based data for use by all parties involved in the industrial air pollution debate, and can serve as an actionable, scientific tool for use by agencies responsible for policing pollution levels and for protecting the public health. This study will quantify the health-service impact of air pollution, and will, for the first time, assign a local price to the cost of treating the healthcare burden attributable to air pollution.

6. Study objectives

6A. General objectives

The general objectives of this study are to map the dispersal of air pollution components in the Ashkelon District, to determine the health outcomes of pollution events, and to evaluate the economic consequences of these events.

6B. Specific objectives

6B(1). Geographic mapping component

1. To quantify the specific role of the Ashkelon District's various pollution sources in producing health-significant air pollution, by means of geographically mapping the spread and concentration of pollutant particles.
2. To identify "pollution hotspots" under various meteorological conditions.

6B(2). Health outcome component

1. To measure the impact of air pollution episodes on diagnosis-specific hospital referrals, hospital admissions and deaths.
2. To measure the impact of air pollution episodes on diagnosis-specific referrals to primary and secondary community healthcare clinics.
3. To identify air pollution thresholds and patterns which are associated with an increase in measurable morbidity in the exposed population.

6B(3). Economic consequences component

1. To estimate the costs to the economy and to the healthcare system of treating the effects of air pollution episodes.
2. To evaluate the cost-benefit ratio of post-episodic treatment of patients, to the alternative strategy of investment in pollution-limiting technologies at the source.

6C. Long-term goal

The long-term goal of the proposed study is to contribute to the redefinition of pollutant emissions standards, in order to achieve outcome-driven levels that reflect the detectable health effects among the exposed population.

7. Study design

7A. Geographic mapping component

7A(1). A dynamic *in silica* pollutant dispersal model will be constructed to describe the directional behavior of pollutants under various meteorological conditions. Input data will include pollutant measurements within the power plant flues and at field monitoring stations, as well as data on wind direction, wind velocity, ambient temperature, humidity and barometric pressure.

7A(2). Geographic mapping and spatial analysis will be carried out using geographic information system (GIS) software. This software uses mathematical processes to convert alphanumeric tabular data, such as pollutant measurements and meteorological conditions, into interactive maps. Since air pollution data has a geographical component that ties it to a physical location such as its point of origin or the location of the air quality monitoring station, GIS allows visualization and geographical analysis that can reveal patterns, relationships, and trends that are not apparent in standard statistical analysis. The GIS component of the proposed study will analyze pollution and meteorological data available from 18 monitoring stations throughout the study region (see below, “Air pollution data”) for the period between 1995-2004.

7A(3). Overlay processing will be used to calculate relationships between pollutant and meteorological data sets, and buffer processing will be used to model geographic pollution gradients. The main outputs will be a series of interactive maps that will indicate “pollution hotspots” under various meteorological conditions.

7B. Health outcome component

7B(1). Study design. A historical-prospective cohort study design will be used to describe the association between air pollution (exposure) and symptom/diagnosis-specific hospitalizations, symptom/diagnosis-specific clinic visits, selected medication use and death (outcomes) in the Ministry of Health's Ashkelon District. This district includes the cities of Ashkelon, Ashdod, Kiryat Malachi, Kiryat Gat, and Sderot and their satellite settlements, and was selected due to the presence of several potential pollution sources in the region.

7B(2). Study population. The study population will include the general population of residents within the Ashkelon District limits between January 1995 and December 2004.

7B(3). Definition of exposure. The exposure under study will be the type, level, constituents and pattern of air pollution on each of the days during this 10-year period. Each day will be classified according to the presence or absence of a pollution event, and the severity of the pollution events will be scored.

7B(4). Definition of outcome. The outcome under study will be the demand for medical attention at the various treatment levels, as measured by the rate of emergency department and community clinic visits for respiratory syndromes; the attributable death rate; and the demand for medications used to treat these syndromes.

7B(5). Outcome window. Health outcomes will be measured for several consecutive days after a pollution event ("outcome window"), in order to capture and best define the immediate and short-term health effects of the event.

7B(6). Controlling for confounding. The statistical analysis will incorporate potential confounding variables such as day of the week, season and holidays, in order to control for the effects of these parameters on the association between exposure and outcome. This will be achieved by comparing the observed outcome rates to those seen immediately prior to the episode period; by comparing the episode period to equivalent dates in adjacent years; and by comparing the episode period to the post-episode period. A positive correlation between the exposure and outcome variables will show that, following a pollution event occurrence, there was a significant increase in the volume of the outcome variables on the same or subsequent days.

7B(7). Source of air pollution (exposure) data. Two separate and independent Unions of Towns for Environmental Protection (UTEPs), located in Ashkelon and Ashdod, operate in the district under study. These unions are companies owned jointly by several municipalities and regional councils, and are under the direction and guidance of the Ministry of the Environment. The UTEPs' charter is to inspect, supervise, monitor, prevent and minimize environmental threats within their regional jurisdictions. Areas of activity and intervention covered by the UTEPs include air and water quality, industrial and solid waste treatment, agro-ecology and noise pollution. The UTEPs in the Ashkelon and Ashdod areas maintain 18 air sampling stations located throughout the regions under their respective jurisdictions, including sampling apparatus located within the power plant flues. Data from these monitoring stations are routinely monitored by the UTEPs for violations of air pollution limits and standards. The recorded data serve individually and collectively as indicators of air pollution in the study area. The available data include half-hourly measurements of SO_2, NO_x, O_3, PM_{10}, $PM_{2.5}$, wind speed, wind direction, ambient temperature and barometric pressure. These measurements are available continuously for the entire study period, and provide the basis for measuring exposure to air pollution in the proposed study. In total, over 20 million data entries are available for quantification of pollution, combinations of which will be used to construct and test definitions of pollution events.

7B(8). Source of health effect (outcome) data: Clinical and pharmacy data will be collected from computerized databases maintained by Clalit and Maccabi Health Services, and will include all primary and secondary clinics that were active in the region during the study period. Together, these two health service providers are expected to yield data on approximately 80% of the insured residents in the region.

Data will be extracted on all clinic visits during this period, and will include date, time, clinic name and location, patient demographics and place of residence, underlying diseases and diagnoses, current diagnosis, drug prescriptions, and disposition. Hospital data will be extracted from computerized emergency department records available from BMC, which is the main provider of hospital services for the study district's population. These records are coded by diagnosis on discharge, and can be electronically linked to additional demographic and administrative data available through BMC. Data on overall and cause-specific deaths will be collected from death notices available through the DHO and registries. This data includes all deaths within the Ashkelon District over the entire study period.

7C. Economic consequences component

7C(1). Healthcare costing. Once the excess demand for medical care has been quantified, a monetary value will be assigned to each item, such as a clinic visit or the price of medication, and the cost to the medical care system of treating the short-term health effects of the pollution episode will be calculated using a static spreadsheet economic model. This cost assessment modelling will provide a highly valid estimate of community health costs, due to the extensive data collection available from community clinics, and will provide a strong estimate of hospital costs based on BMC data.

7C(2). Overall economic costing. Overall costs to the economy can be further elicited by including the additional indirect economic variables of lost work days and decreased productivity in the model.

7C(3). Sensitivity analysis. Probabilistic sensitivity analysis using second-order Monte Carlo simulation will be used to analyze uncertainty in the data. This approach assigns a distribution to model parameters, and random values from those distributions are taken for each sample of the Monte Carlo simulation. This probabilistic sensitivity analysis will allow the generation of confidence intervals around costs and effects, and will provide a robust economic model for the costs of treating the health effects of air pollution events.

7C(4). Cost-benefit analysis. The costs of introducing various pollution abatement technologies at the pollution source will be modelled, and a cost-benefit analysis will be conducted. This analysis will compare the cost-of-healthcare model to the cost-of-pollution-abatement model, and will explore the potential for cost savings through a national strategy of investment in pollution abatement technologies as an alternative to the current strategy of expenditure limited to the medical treatment of pollution-related illness.

8. Statistical analysis

Spatial analysis, including overlaying and buffering, will form the basis of data analysis in the geographic component. For the health effects component, incidence rates of the various health effects will be compared between the pollution episodes and non-pollution intervals, initially using a univariate approach. Subsequent multivariate regression analysis will provide the basis for establishing the presence and strength of associations between individual and combined air pollutant levels and health outcomes, while controlling for environmental variables with known health effects, such as season, temperature and barometric pressure. Static spreadsheet modelling with probabilistic sensitivity analysis will be used to analyze data in the economic component.

9. Preliminary results

The proposed study plans to elaborate on aspects of this topic that have not been addressed to date: geographic mapping of pollutant dispersal in the Ashkelon District; identification of local pollution levels and patterns that result in detectable increases in health outcomes; measurement of the healthcare burden of pollution episodes; quantification of the costs to the economy of treating patients affected by pollution episodes; and cost-benefit comparisons of alternative prevention strategies. No data are available as yet for these novel research issues. However, in preparation for this research, SISPAQ partners cooperatively explored study feasibility, engaged in limited data exchange, conducted preliminary data analysis, and investigated alternative research methodologies.

10. Additional sources of funding

No funding for this study has been requested or provided by additional sources.

11. Resources

Michael Huerta, MD, MPH, is a specialist in public health and epidemiology. He is currently an epidemiologist at the Barzilai Medical Center and Ashkelon District Health Office, where he coordinates epidemiologic research on various regional, community, and clinical topics. Dr. Huerta, who holds the rank of major in the Israel Defense Force Medical Corps, has been an active researcher and interventional epidemiologist at the IDF Army Health Branch for more six years, and in his most recent assignment served as IDF Epidemiology Section Head. Dr. Huerta is proficient in study design and implementation as well as in biostatistics and epidemiologic methodology, and he has received several research grants for the study of the epidemiology of both infectious and non-infectious diseases. Dr. Huerta is affiliated with the Epidemiology Department of the Faculty of Health Sciences at Ben Gurion University of the Negev.

Michael Gdalevich, MD, MPH, is a specialist in public health and epidemiology, and serves as Deputy District Health Officer of the Ashkelon District Health Office. His primary fields of academic interest include advanced research methods in the epidemiology of infectious and chronic diseases. For the last two years Dr. Gdalevich has been a member of the Ashkelon District-BMC Power Plant Pollution Steering Committee. Additionally, Dr. Gdalevich is Regional Coordinator of the Middle Eastern Consortium of Infectious Disease Surveillance (MECIDS), and maintains an ongoing research partnership with the European Program for Interventional Epidemiology Training (EPIET).

Professor Haim Bibi, MD, is a specialist in pediatric pulmonology, and heads the pediatric intensive care unit at the Barzilai Medical Center. Professor Bibi has accumulated more than 15 years of experience in the study of the effects of air pollution on the lung health of adults and children in the Ashkelon region.

Jacob Haviv, MD, MPH, is a specialist in public health, and is currently completing a second medical specialty in occupational medicine. He holds the rank of colonel in the IDF, and serves as Chief Medical Officer of the IDF Central Command. He has previously served as Head of the IDF's Occupational Health Branch and as a specialist at the Epidemiology Section of the Army Health Branch.

Shimon Scharf, MD, MPH, is Director of the Barzilai Medical Center and Ashkelon District Health Officer. He is a specialist in health administration and ear, nose and throat surgery, and has extensive experience in the research of clinical and public health issues. He is a senior lecturer with the Faculty of Health Sciences at Ben Gurion University, and has collaborated on several studies of the health effects of air pollution in the Ashkelon District.

BMC has been a leader in research on the health effects of environmental air pollution for over 15 years. Professor Bibi serves as Chairman of the BMC Power Plant Pollution Steering Committee, an independent panel of experts that oversee the research activities conducted at BMC in accordance with the Israel Electric Company's licensing terms. The SISPAQ project coordinators have been directed by the Steering Committee to propose innovative research methods, and they receive full professional, academic and methodological support from the committee's experts. They have built a comprehensive database of air pollution and health outcomes that can serve as a tool for current and future research initiatives.

Within the framework of BMC, the project coordinators have unlimited access to web-based resources, a complete medical library, and expert medical consultants in all clinical fields. In their capacities as academic faculty of the Tel Aviv and Ben Gurion Universities, the project coordinators have access to databases maintained by these institutions, as well as to expert consultations in research methodology.

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