Paper from: *Air Pollution X*, CA Brebbia & JF Martin-Duque (Editors).
ISBN 1-85312-916-X

The development of an Air Pollution Abatement Strategy for Cairo, Egypt; analytical support for decision-making under uncertainty

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Abstract

The major objective of this paper is to provide decision-makers sufficient information to initiate an Air Pollution Abatement Strategy for Cairo. The purpose of the analysis was to identify the major air pollution activities and to assess the relative importance of these activities to the economy by assessment of the potential economic benefit gained through successful abatement of their pollution. Estimates of health impacts resulting from air pollution indicate annual economic losses of US$ 1.3 billion, representing approximately 6 percent of the gross regional product. Urban solid waste burning, industrial waste generation, industrial heavy fuel use and diesel fuel consumption in the transport sector are the major sources of particulate air pollution. Urban solid waste burning contributes 25% of the total particulate load (TPL), which represents a potential annual economic benefit (PAEB) of US$ 300 million from eradication of this pollution source. Industrial waste generation is responsible for 22% of TPL; PAEB US$ 266 million. Industrial fuel (mazut) consumption contributes approximately 50% of the pollution load from all fuel consumption (21% TPL; PAEB US$262). Diesel fuel consumption is the other major fuel that significantly contributes to particulate loading (19% TPL; PAEB US$232 million). Agricultural burning is a major contributor to air pollution on a seasonal basis (annual average 12% TPL; PAEB US$ 146 million).

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1 Introduction

Urban air pollution is one of the greatest environmental problems facing Egypt today [1]. The Egyptian environmental Affairs Agency has been monitoring air pollution in Cairo over several years with the assistance of donor-funded projects [2,3]. Their results have shown that particulate pollution is the most significant air pollutant at this time. This paper presents the re-analysis and consolidation of this data into a format that provides information that can support policy-level decision makers in designing an air pollution abatement strategy.

2 Methodology

This paper presents supplementary analysis of the CAIP source attribution [4] and ambient particulate [5] data combined with additional analysis of pollution loading from fuel use using input output modelling.

2.1 Attribution study

Briefly, the source attribution study used the sampling protocol of Watson et al [6]. Aerosol mass was determined gravimetrically and a basic suite of elemental concentrations was determined through an array of analytical procedures including: X-ray fluorescence, ion chromatography, thermal/optical reflectance, atomic absorption, colorimetric, and gas chromatography carried out at the Division of Atmospheric Sciences, Desert Research Institute Reno Nevada USA. The current Chemical Mass Balance model software (EPA/DRI version 7) was used to stochastically develop, (through variance of least squares) the set of linear equations, which expressed ambient concentrations of chemical species as the sum products of source contributions and composition profiles [7]. Ambient particulate PM10 samples were collected concurrently at all sites by sampling for 24 hours every six days using AIRmetrics samplers™ . The mass of particular material collected was determined gravimetrically, after desiccation to constant weight [5].

The supplementary analysis of the attribution study disaggregated the geologic fraction to estimate the level of background particulates by deriving a decay curve of the "geologic" fraction emanating from the site of cement factories situated to the south of the city. Comparison of the analysis between the "winter" and "fall" results showed a distinct seasonal difference in the geologic and vegetative fractions which were attributed to the seasonal burning of crop residues in the Nile delta due north of the city. Ammonium chloride particulates, which formed a major fraction of the particulates, were attributed to urban waste burning, the ammonia coming from vegetative sources and the chloride derived from hydrogen chloride liberated from the low temperature burning of polyvinyl chloride plastic [8, 9].

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2.2 Input-output analysis

Assessment of the importance of different sources was based on data from a source attribution study and input-output analysis of fuel use. Data on the transportation fleet and industrial and transportation fuel consumption rates for the year were provided by various government reports [10, 11, 12, 13, 14]. The various proportion and type of fuel used by different components of the transport sector was developed using an input-output model, incorporating various components of the transport fleet, their fuel type and estimated mileage.

The level of particulate output for each class of vehicle was generated using coefficients from the RAINS [15], COPERT [16] and EPA [17] models for transport and fuel use in developing countries [18]. Loading estimates were determined in terms of kg per tonne fuel used or g of pollution load per km driven. Both sets of output data were compatible and the median level was used for additional analysis. The model incorporates sensitivity analysis for the age of vehicles, the annual mileage in the different classes, and the fuel consumption of the different classes, and takes into account different sizes of diesel engine and the vehicles that generate different levels of pollution for the same amount of fuel consumed.

The sulphur content of the fuel is one of the major characteristics of the fuel that determines the amount of particulates it will generate when burnt. The analytical model incorporates this relationship. The relationship, between sulphur content of fuel and particulate load, were treated separately for the four categories of diesel vehicle.

2.3 Population exposure, health risk, and potential economic benefits

The annual daily average distribution of PM_{10} was mapped using Arc Info™ GIS software and layered on administrative district boundary base map provided by the Central Agency for Public Mobilisation and Statistics (CAPMAS). Population data from the 1996 census, associated with these administrative boundaries allowed estimation of population exposure

Assessment of the potential economic benefits was based on the estimated exposure suffered by the population of greater Cairo, developed through GIS map overlay of the monitored annual daily average ambient PM_{10} pollution on district level population. Globally accepted coefficients were then used to assess potential health impacts from this exposure, and their cost to society [19, 20, 21]. The economic coefficients are based on health treatment costs, loss of production and contingent valuations to provide an indication of the potential benefits that could be gained from pollution abatement. Valuations are weighted through application of relative GDP of the region concerned.

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3 Results

3.1 Attribution Study

The decay curve of "geologic" fraction of the PM_{10} particles from the cement factories south of Cairo gradually declined to a background of about 50 ug/l. This background was subsequently subtracted from the ambient PM_{10} to estimate pollution exposure.

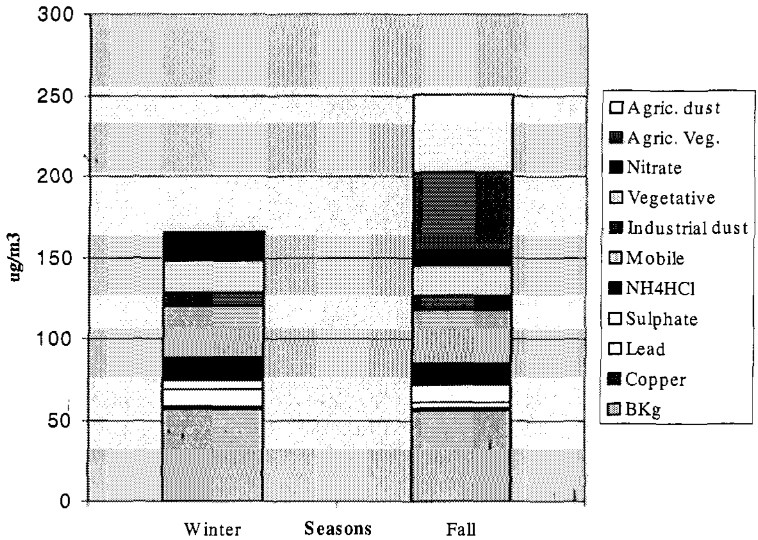

Figure 1: Re-analysis of the PM_{10} attribution study in the fall and winter

A distinct seasonality of pollution load is seen in Figure 2 of the attribution study, which was corroborated by the analysis of the ambient particulate PM_{10} monitoring Figure 2.

Figure 3 illustrates the contribution of various "economic" activities to the particulate load developed from the attribution study if: the agricultural dust and agricultural vegetative fraction of the fall are attributed to seasonal agricultural burning; the vegetative fraction determined in the winter sampling and the NH_4Cl fraction are attributed to household waste burning; the metal fractions and geologic fraction in the winter above background are attributed to industry; and the nitrate, sulphate and mobile source fractions are attributed

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to fuel and mobile source emissions. The relative contribution of agricultural burning assumes that intense agricultural burning takes place on average for two months of the year.

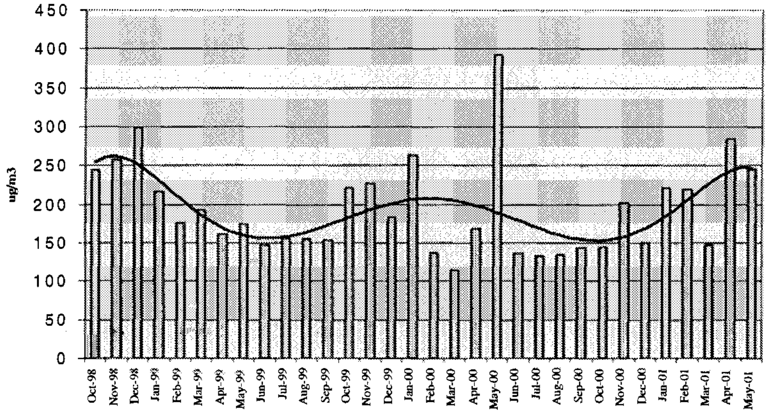

Figure 2: Monthly daily average of PM_{10} across monitoring stations, 1999/2001

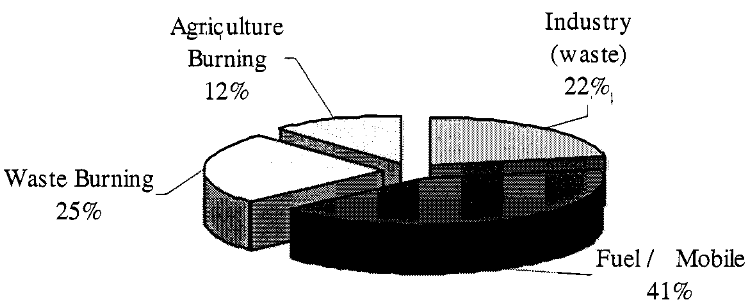

Figure 3: Contribution of various economic activities to particulate air pollution

3.2 Input-output analysis

Input-output analysis allowed the disaggregating of the Fuel / Mobile fraction determined from the attribution study, Figure 4. The model accounted for 95% of the gasoline and 75% of the diesel sold within greater Cairo. This makes sense in that not all fuel purchased in greater Cairo is consumed within greater Cairo, and that there is a fair amount of wastage and evaporation of fuel within the delivery infrastructure and from standing vehicles.

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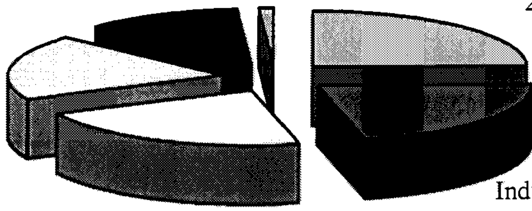

Figure 4: Dis-aggregation of mobile and fuel sources derived from the input-output model.

3.3 Population exposure, health risk, and potential economic benefits

Figure 5 illustrates the distribution of particulate air pollution and the population exposure in Cairo. Particulate pollution levels are taken as those above the estimated annual daily average of 50ug/m^3 . The estimated health impacts of this exposure are given in Table 1. These do not include impact from SOx, NOx and Ozone, as these estimates are less reliable due to the less extensive geographical coverage of the monitoring stations.

Table 1: Estimated health impacts from exposure to PM_{10} air pollution in Cairo

Health Impacts	Total increase (medium)	Total increase (low)	Total increase (high)
Mortality	5,211	3,164	7,879
Morbidity			
Increase in Respiratory Hospital Admissions	9,343	3,613	14,949
Asthma Attacks	8,969,369	5,979,579	12,146,020
Emergency Room Visits	298,979	224,234	373,724
Restricted Activity Days (Adults 15+)	44,644,398	22,516,305	70,654,613
Lower Respiratory Infections (Children<15)	793,153	469,321	938,643
Acute Respiratory Symptoms Adults (net; total less RADs)	130,439,285	62,113,945	198,764,625

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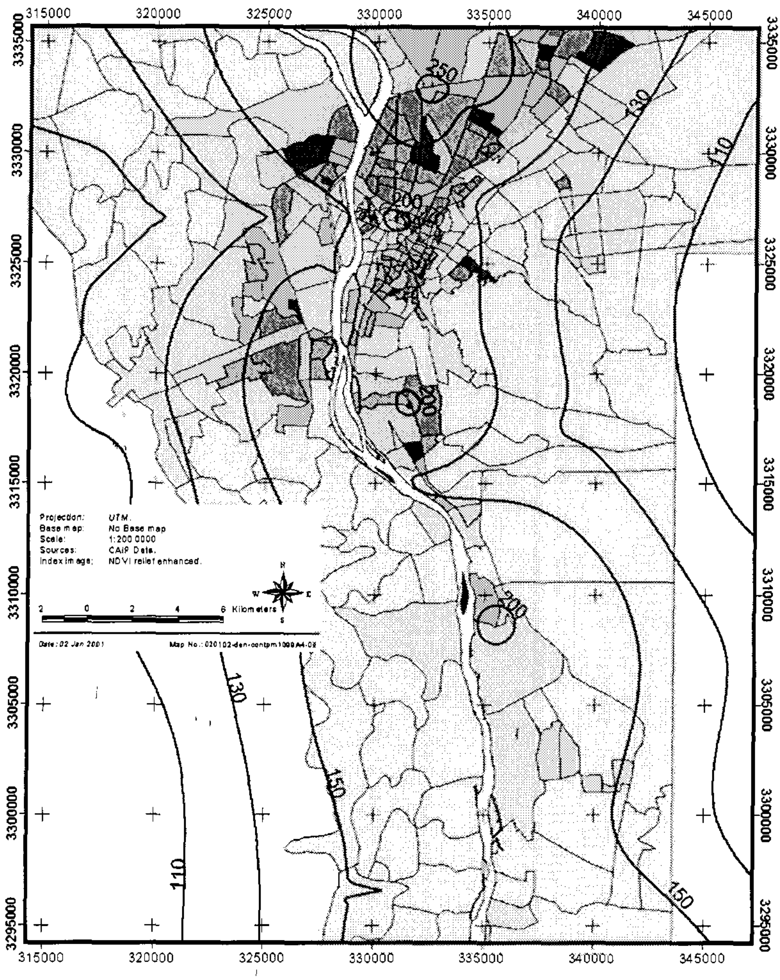

Figure 5: Annual average daily ambient particulate concentration PM_{10} ug/m^3, Cairo, 1999.

Greater Cairo has a population of approximately 16 million, the population exposure map area accounts for approximately 11 million, and thus all estimates tend to under-value the impact.

Estimates of the economic value of health impacts due to above background PM_{10} exposure are in the order of US$ 1 $\pm$ 0.5 billion annually. The range is dependent on the upper and lower coefficients used in the estimations. Less certain estimates based on of the potential impact of SO_2, NOx, and Ozone are in the order of US$100 million, US$ 10 million, and US$ 200 million respectively, based on the assumption that their distribution is similar to that

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of PM_{10}. This gives a median present value of approximately US$ 10-12 billion, using a 10% discount rate.

4 Summary and Recommendations

The major priorities for an air pollution abatement strategy in Cairo are targeted interventions to dramatically reduce the burning of urban waste, industrial emissions, the use of high sulphur content heavy fuel oil in industry, and the reduction of sulphur content of diesel and reduction of diesel usage in general. All of these activities contribute to equal extents to the particulate pollution load borne by Cairo. In addition seasonal agricultural burning adds a significant level of pollution during the fall months. This effect is exacerbated by the frequent occurrence of air temperature inversions at this time of the year, which effectively limits the atmospheric dispersion of the smoke coming from the burning waste.

The reduction of urban waste burning will be reduced by a more effective garbage collection and disposal system that is now being introduced, though contracting out to the private sector. In the short-term agricultural burning should be managed and limited to times when there is no air inversion, e.g., during daylight hours of the afternoon. Mid-term an alternative use for agricultural waste needs to be found. The use of low-grade heavy fuel oil by industry is being discouraged, with a switch to natural gas. Currently, there is a major effort to increase provision through development of new infrastructure to rapidly increase use of major reserves of natural gas found in Egypt.

Diesel fuel use, especially high sulphur fuel, is currently encouraged in Egypt by the massive subsidy provided by the government. This subsidy is in the region of US$ 1 billion annually dependent on the crude oil price. This provides a perverse incentive for over consumption. Sixty percent of the PM_{10} load from diesel consumption is generated by microbuses and light goods vehicles, both categories could be replaced by gasoline or natural gas power. Certainly, this would be encouraged by a gradual reduction in the diesel fuel subsidy. Heavy goods vehicles and the larger town buses will remain diesel powered, but the sulphur content of the fuel should be reduced.

The task of reducing industrial emissions is much more complex than the other categories and more in-depth analysis is required to develop a strategic plan for industrial pollution abatement. Currently, the Egyptian Environmental Affairs Agency, is working with different sectors of industrial to encourage cleaner production applications. A comprehensive geo-referenced industrial database needs to be developed to allow a more effective assessment of potential polluters and more effective monitoring of the situation.

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Acknowledgements

The author would like to thank the Cairo Air Improvement Program for providing much of the ambient air pollution data, and the Egyptian Environmental Information System project, funded by CIDA Canada, for support in the geographic information systems analysis.