HEALTH, ECONOMICS AND AIR POLLUTION CONTROL STRATEGIES IN JORDAN

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ABSTRACT

This paper estimates the health impacts of air pollution in Jordan, their economic significance, and potential strategies for air quality improvement in the future. The focus of the analysis is on fine particles, expressed as PM_{10}, concentrations of which exceed international standards by a significant degree in several Jordanian cities. The paper draws on European and US experience to quantify and value impacts on mortality and morbidity, with some adjustment for Jordanian conditions. This raises important issues concerning the reliability of health impact assessment in regions where primary research data are limited. Implications for policies on air quality management are discussed.

Effects investigated include premature mortality, bronchitis, cough and exacerbation of asthma. It is estimate that total annual damages from exposure to air pollution in Jordan could be as high as 1 to 2 billion Euro. This result should be regarded as preliminary as it could be subject to significant refinement in future work. However, it usefully highlights that the problem is potentially serious and worthy of further consideration.

Priorities for future work have been described. The most immediate of these relate to research to make the response functions and valuation data used more relevant to Jordan than they currently are. Considerations for extending the work from impact assessment to the development of air quality management strategies are also presented.

INTRODUCTION

The objective of this paper is to provide a preliminary quantification of the effects of air pollution on health in Jordan. The results should be of interest for consideration of national priorities for environmental protection, and also in the development of strategies for reducing air pollution. The analysis can help policy makers answer a number of questions, for example:

- How important is air pollution?
- Which sources of air pollution cause the greatest impacts?
- How do the benefits of emission control compare to the costs (cost benefit analysis)?
- And so on.

In recent years the results of epidemiological work have shown significant relationships between many air pollutants, most notably fine particles and ozone, and various health states. Other pollutants of concern include sulphur dioxide, nitrogen dioxide, carbon monoxide, benzene, PAHs (poly-aromatic hydrocarbons) and metals, particularly lead, mercury, arsenic, nickel, cadmium and chromium. Particularly since the early 1990s, the results of this research have been used to quantify the health impacts of air pollution in order to inform

policy. Monetary valuation of impacts has also been used for cost-benefit analysis, particularly on behalf of the European Commission [e.g. 1-3] and the USEPA [4].

METHODS AND DATA

The general method commonly used to quantify both health and non-health impacts of air pollution, the 'impact pathway approach' proceeds in a logical and stepwise fashion through the release of pollutants, through their dispersion and chemistry, to quantification of population exposure, impacts and economic value [5].

This analysis of impacts in Jordan is based on assessment of damages solely in relation to PM_{10}. The overall effect of the decision to quantify for PM_{10} alone is that (all else being equal), there is likely to be some underestimation of the health effects of air pollution. However, experience elsewhere (in China as well as western countries) suggests that PM pollution generates the largest share of health impacts. Any underestimation may therefore be of limited importance at the present time.

In the absence of detailed concentration maps for the country, a series of scenarios have been investigated:

1. **Scenario 1 (10 $\mu g.m^{-3}$ change):** A change in average PM_{10} exposure of 10 $\mu g.m^{-3}$ across the whole of Jordan. This will be illustrative of the benefits of incremental change in pollution levels.
2. **Scenario 2 (Range for the whole of Jordan):** Assuming that available data from monitoring stations are truly representative of urban exposure in general (as opposed to a restricted area around each monitoring site), the following ranges are assumed for average PM_{10} exposure in the cities of Jordan, which cover 73% of the population (3.87 million people):

Lower bound	55 $\mu g.m^{-3}$
Upper bound	94 $\mu g.m^{-3}$

   The other 27% of the population are assumed to be exposed to a level of 20 $\mu g.m^{-3}$ for both the lower and upper bound analysis. The figure of 20 $\mu g.m^{-3}$ is not dissimilar to concentrations in rural parts of Europe. In the absence of Jordanian data for such locations it has been selected as illustrative of the concentrations that may be present.
3. **Scenario 3 (City case studies):** Based on monitored data, the following are assumed for the average PM_{10} exposure in the cities of Amman (population 2.1 million), Zarka (population 560,000) and Fuhais (population 23,000):

Amman	94 $\mu g.m^{-3}$
Zarka	90 $\mu g.m^{-3}$
Fuhais	63 $\mu g.m^{-3}$

The following response functions have been taken from the NewExt Project [6] for the European Commission, drawn from extensive reviews of the European and US literature since 1990. It is assumed that there is no threshold for effect of particles on health.

Table 1 – Concentration response functions used in this analysis for PM_{10} exposure (units: cases/person/year/µg.m^{-3} PM_{10}). Source: various, collated by the NewExt project for the European Commission [6].

Health endpoint	Function
Cough in asthmatic children	1.87E-03
Cough in asthmatic adults	9.39E-03
Bronchodilator usage in asthmatic children	5.43E-04
Bronchodilator usage in asthmatic adults	4.56E-03
Chronic cough in children	4.14E-04
Restricted activity days	1.98E-02
Chronic bronchitis (new cases)	3.92E-05
Mortality - Years of Life Lost (YOLLs)	2.90E-04

Data on incidence of disease and the state of health of populations in western countries are built into these functions. Application in other countries raises additional uncertainty because of differences in health status and health care in different countries. Future analysis could adapt the functions to be more relevant to Jordan.

Valuation work in the US and Europe is based around the 'willingness to pay' (WTP) concept that seeks to cover all components of ill health, including factors such as pain and suffering as well as those with a direct economic component, such as medical treatment. WTP is derived by costing out those elements of the total cost that can be described directly, and using survey based techniques to elicit the value of the elements that cannot. Results have been criticised on the grounds that costs attributed to elements like 'pain and suffering' are not 'real' costs. However, these elements are undeniably important, and if the objective of the analysis is to identify ways in which human welfare can be maximised they should clearly be accounted for.

It has not been possible to collect willingness to pay estimates specifically derived for Jordan in the course of this preliminary assessment. Instead, values are converted from data collected in the ExternE Project series in the European Union by multiplying by a factor of 0.2, which is equivalent to the ratio of Purchasing Power Parity adjusted GNP/capita for Jordan (around US$4,300/capita) compared to the EU (around US$22,000/capita) for 2004.

Valuation data, again taken from the EC's NewExt project [6], are given in Table 2, together with assumed values for Jordan derived as described above by multiplying the EU values by a factor of 0.2 to account for differences in PPP-adjusted GDP/capita.

RESULTS

As noted above, the analysis presented here is focused around quantification of the effects of PM_{10}, partly using it as a marker for the impacts of other air pollutants. Results for Scenario 1, a 10 µg.m^{-3} change in concentration, are given in full in Table 3, showing the breakdown between different health endpoints. Totals for the other scenarios are then given in Table 4. Mortality accounts for about 60% of the total damage.

Table 2 – Valuation data used in this analysis (all data in Euro)

Health endpoint	European values from NewExt 2004	Equivalent Jordanian values (Euro)
Cough in asthmatic children	45	9
Cough in asthmatic adults	45	9
Bronchodilator usage in asthmatic children	40	8
Bronchodilator usage in asthmatic adults	40	8
Chronic cough in children	240	48
Restricted activity days	110	22
Chronic bronchitis (new cases)	169,300	33,860
Chronic Years of Life Lost (YOLLs)	50,000	10,000

Table 3 – Estimated annual impacts and associated values for a 10 μg.m^{-3} change in PM_{10} exposure across the whole of Jordan (Scenario 1)

Scenario 1 – 10 μg.m^{-3} change in PM_{10} Health endpoint	Cases	Value – Million Euro
Cough in asthmatic children	99,671	0.9
Cough in asthmatic adults	500,487	4.5
Bronchodilator usage in asthmatic children	28,942	0.2
Bronchodilator usage in asthmatic adults	243,048	1.9
Chronic cough in children	22,066	1.1
Restricted activity days	1,055,340	23
Chronic bronchitis (new cases)	2,089	71
Mortality - Years of Life Lost (YOLLs)	15,457 YOLLs	150
Total		**260**

Table 4 – Summary of total annual economic damage estimates for Jordan for the scenarios considered.

Scenario	Value – million Euro
Scenario 1 – 10 μg.m^{-3} change in PM_{10}	260
Scenario 2 – lower bound for Jordan	1,200
Scenario 2 – upper bound for Jordan	1,900
Scenario 3 – Amman, central estimate (population 2,080,000)	940
Scenario 3 – Zarka, central estimate (population 560,000)	240
Scenario 3 – Fuhais, central estimate (population 23,220)	7

These results are incomplete, in that they omit effects of some air pollutants (ozone, lead, H_2S, benzene, etc.), and even for particles omit some impacts (for example, work on the development of functions to describe the relationship between particles and infant mortality is ongoing in the EC's CAFE programme). However, they suggest that even for a small city such as Fuhais the total annual damage is likely to be valued at several million euro, whereas for Amman the total annual damage is likely to be of the order of 1 billion euro, and for the country as a whole perhaps twice that.

DISCUSSION

The results presented here provide first estimates of the health effects of air pollution in Jordan. Although preliminary, they suggest that these effects are significant and are worthy of more detailed consideration with a view to the development of an air quality management strategy for the country.

There are two general ways in which they could be made more useful:

1. Refinement of methods to ensure that the functions and other data used are better representative of the situation in Jordan.
2. Integration of results within frameworks for developing air quality policy.

On the first point, the following priorities are identified for further work, covering refinements at each stage of the impact pathway (Modelling and mapping pollutant levels; Quantifying exposure to air pollution; Quantifying impacts; and Valuing impacts):

Modelling and monitoring pollutant levels

The analysis presented in this paper has been based around the outputs from monitoring stations in Jordanian cities. Future work should ideally move to the use of models that produce output in a form that can be combined with data on population distribution (e.g. through the use of GIS) to improve the resolution of data (this would clearly need to be calibrated against monitored levels). Models such as RiskPoll [7] provide an integrated solution to dispersion modeling, impact assessment and valuation from specific sources. Another priority is to develop knowledge of ozone concentrations in the country. Quantified effects of ozone are considered additive to those of PM_{10} – the problem of possible double counting which affects quantification of SO_2 and NO_2 impacts as well as PM_{10} effects is not thought to apply.

Quantifying exposure to air pollution

The main improvement that could be made for exposure assessment in comparison to the present paper is the use of data in GIS format to combine population and pollution levels to describe exposure of the population. The geographic scale for the analysis should be varied depending on its objectives – it is clearly appropriate to perform assessment of the health impacts in a city at a finer level of resolution than in a full national analysis.

Quantifying impacts

There are several areas where assessment of health impacts could be improved, primarily to make the analysis more specific to conditions in Jordan:

1. Taking account of the effects of a larger number of pollutants.
2. Quantifying additional types of impact to those reported here (e.g. effects of PM exposure on infant mortality).
3. Improving the way that effects of long-term (chronic) exposure on mortality are quantified, using life table methods that account for the age structure of the population. This should be relatively easy to do, but would lead to a major improvement in the quality of the results.
4. Accounting for differences in morbidity rates in the Jordanian population compared to the populations originally considered in the epidemiological work from which response functions have so far been derived.

Valuing impacts

Again, the priority is to refine the input data so that it better reflects conditions in Jordan.

The format of modeling needs to reflect the questions that are asked of the analysis by policy makers. This type of work can be used to highlight the pollutants and sources of most concern to health, allowing the development of closely targeted strategies for dealing with air quality impacts. In developing strategies for air quality improvement several issues should be accounted for:

1. There is a lot of experience elsewhere in the world in improving air quality, and a good knowledge of the measures that are most cost-effective;
2. Many options for air quality improvement are based on efficiency improvements or planning systems that can save money. Expensive technical solutions are only one part of the equation.
3. Local, national and regional strategies all have an important role to play.

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