Valuing Environmental Costs due to Automobile Pollution in Pakistan

M. Qamar uz Zaman

I. Introduction

In the current era, increased attention is being paid to protect the environment in developing countries. The concern stems primarily from recent advances in information concerning health problems associated with pollution. The extent of the deep-seated dangers present has motivated detailed studies and consequent pollution abatement programmes to be adopted by several countries. However, the evaluation of projects and policy reform for environmental effects in Pakistan has been rare. The task thus is posed to provide credible estimates of the benefits that can be provided by pollution abatement, and the corresponding costs.

Major pollutants emanating from vehicular emissions include carbon monoxide (CO), carbon dioxide (CO_2), sulfur dioxide (SO_2), particulate matter (PM10), lead (Pb), nitrogen oxides (NO_x), and ozone (O_3). The present study is an effort to estimate the social costs and benefits through the reduction of these pollutant emissions from motor vehicles in Pakistan. The approach applied is an empirical valuation procedure where costs and benefits are given monetary values, to get to a more socially desirable output level of production.

The next section of the paper provides a background description of the air pollutants emanating from motor vehicles and the associated health effects. Section-III gauges the costs resulting from these pollutants and also provides a detailed description of the procedure utilised for the purpose. Section-IV illustrates the corresponding costs of pollutant removal. The benefits and costs are assimilated in Section-V, and concluding remarks and recommendations are stated in Section-VI.

II. Background

Emissions in gasoline fueled vehicles occur primarily through the exhaust, engine crank case, carburetor, fuel line and fuel tank. Principal pollutants emitted from such vehicles are CO, HC, NO_x, and Pb. Pollutants, primarily in the form of PM10, NO_x, SO_2, CO, and HC, emitted from diesel fueled vehicles emanate incipiently from the exhaust.

Particulate matter: PM10 is suspended inhalable particulate matter with an aerodynamic diameter of 10μm or less. Particulate matter is discharged from a broad magnitude of sources including power plants, industrial processes, vehicular traffic, and domestic coal burning. Adverse health effects linked to PM include increased mortality, morbidity, reduced lung function, and respiratory diseases such as pneumonia, asthma, and bronchitis. It is estimated that approximately 13.9 per cent of all annual world PM emissions are attributable to the transport sector.[1] Two separate studies in Lahore put the figure for the city at 14.7 per cent and 26 per cent respectively.[2] Ambient air concentrations of PM 10 are found to be dangerously high for almost all major urban centers in Pakistan (See Table-1).

Lead: Lead is an extremely hazardous, heavy metal. Discharges from vehicles are the sole biggest source of lead in the biosphere. Medical evidence shows that lead has significant adverse health effects, including the slowing down of the neurological development of children, hypertension and cardiovascular problems in adults. Lead additionally exacerbates the problem by impeding the use of catalytic converters in cars. Though a large total of countries now furnish low leaded or unleaded gasoline, consumers in Pakistan can only buy gasoline with a high concentration of lead (levels between 0.42 to 0.82 g Pb/I).[3] Studies conducted by researchers unveiled the fact that school children in Karachi had blood lead levels more than double the WHO limit.[4] As depicted in Table-1, ambient air concentration lead levels are hazardously high in several urban localities in Pakistan.

Carbon monoxide (CO): Carbon monoxide is a colourless and odorless gas. Absorbed through the lungs it bonds with hemoglobin (Hb) to form carboxyhemoglobin (COHb), which lowers the oxygen level in blood.[5] Intake of the gas also impairs perception and thinking, slows reflexes, and may cause drowsiness, angina, unconsciousness, or death (Romieu 1992). It is theorised that people most at risk to the effects of CO comprise those with extant cardiovascular or chronic respiratory problems, the aged, infant children and fetuses. Motor vehicles are the main contributors to anthropogenic CO emissions. Worldwide anthropogenic CO emissions for 1995 were estimated at 350 million tonnes, 59 per cent of which were contributed by the transport sector.[6] Wijetilleke et. al. (1993), meanwhile, estimate through a survey of twenty-one countries that 69.8 per cent of all CO emissions are attributable to transport. Comparable figures for Pakistan have been calculated to be much

[1] Wijetilleke L. and Karunaratne R.A., Air Quality Management: Considerations for Developing Countries. 1993. Pg.65.
[2] EGC, Sectoral Study on Environmental Technology and Infrastructure, 1998. Pg.3-25. & Tariq N. and Ali W, NCS Sector Paper on Municipal Discharges. 1985.
[3] Faiz A., Weaver C.S., Air Pollution from Motor Vehicles, 1996.
[4] Naim P., Take a deep breath, 1996.
[5] Onursal B. and Gautam S.P., Vehicular Air Pollution - Experiences from Sevel Latin American Urban Centers. 1997. Pg.26.
[6] ibid. Pg.17.

higher. Two separate studies conducted in Lahore concluded that the contribution of traffic to CO emissions in the city were 92.8 per cent and 96 per cent respectively.[7] It has been assessed that the average vehicle in Pakistan emits 25 times the carbon monoxide emitted by a comparable vehicle in the USA.[8] However, though concentrations have been found to be high in several urban localities in the country they have not reached dangerous levels. Ambient air concentration levels for major cities in the country, and corresponding WHO guidelines are depicted in Table-1.

Nitrogen Oxides (NO_x): NO_x is a collective term used to describe two species of oxides of nitrogen: nitric oxide (NO) and nitrogen dioxide (NO_2), the main nitrogen oxides emitted by vehicles. NO_2 which is formed by the oxidation of NO, is generally regarded as being more important from the point of view of human health. Accordingly, data on health hazards, and standards and specifications are commonly stated in terms of NO_2 rather than NO_x. Exposure to NO_2 is linked with heightened susceptibility to respiratory infection, increased airway resistance in asthmatics, bronchitis, bronchopneumonia, and decreased pulmonary function.[9] Motor vehicles are known to be the main contributors to anthropogenic NO_x emissions. Worldwide anthropogenic NO_x emissions for 1995 were estimated at 93 million tonnes, 43 per cent of which were contributed by the transport sector.[10] Wijetilleke et al. (1993), meanwhile, estimate through a survey of twenty-one countries that 48.9 per cent of all NO_x emissions are attributable to transport. While other urban centers in Pakistan show a controlled level of NO_x emissions, the level in Karachi is found to be dangerously high, much above the ambient air quality standards proposed by the WHO. Table-1 shows concentrations for different urban localities in the country.

Ozone: Ozone is a strong oxidising agent, which makes it highly reactive. Ground level ozone is a major component of smog in urban areas, and vehicles are the leading anthropogenic emission source of its precursors. Adverse health effects caused by ozone include severe damage to lung tissues, optical and nasal irritation, coughing, thoracic pain, increased mucous production, chest tightness, fatigue, and debility. Emission levels in Pakistan are found to be well within WHO guidelines.

Sulfur dioxide: SO_2 is a stable, non-combustible, achromatic gas. The most important source of emissions of SO_2 are fossil fuel combustion,

---

[7] EGC, Sectoral Study on Environmental Technology and Infrastructure, 1998. Pg.3-25. & Tariq N. and Ali W., NCS Sector Paper on Municipal Discharges, 1985.
[8] IUCN, The Pakistan National Conservation Strategy. Pg.83.
[9] Onursal B. and Gautam S.P., Vehicular Air Pollution - Experiences from Seven Latin American Urban Centers, 1997. Pg.26.
[10] ibid. Pg.17.

and the smelting of non-ferrous ores. Adverse health effects of the gas include coughing, phlegm, chest discomfort, and bronchitis. Annual global emissions of SO_2 are estimated at 294 million tonnes, from which 160 million tonnes are ascribable to anthropogenic sources.[11] Wijetilleke et al. (1993), estimate that approximately 5.8 per cent of SO_x emissions in the world emanate from the transport sector. Najeeb Murtaza (1991), estimates a similar figure of 4.47 per cent for Pakistan. Annual mean concentrations in most European cities are estimated to be below 100 μg/m^2.[12] Ambient air level concentrations are found to be higher than those prescribed by the WHO in the cities of Karachi and Lahore (See Table-1).

Table-1: Ambient Air Quality Levels in Pakistan (μg/m^3)

	PM10	Pb	CO	NO_2	O_3	SO_2
Karachi[13]	191.79	5.00	Na	1035.02	0.00	96.99
Lahore[14]	306.25	2.52[15]	2720.51	50.90	64.85	57.72[16]
Rwp & Ibd[17]	148.78	2.34[18]	Na	105.38	Na	Na
Peshawar[19]	na	3.09[20]	834.00	53.00	30.00	1.00
Faisalabad[21]	361.25	2.03[22]	2520.06	44.46	51.44	12.30
Multan[23]	518.75	1.61[24]	1890.04	38.06	42.51	6.61
Gujranwala[25]	281.25	2.39[26]	3178.71	45.87	58.91	6.81
Hyderabad	na	1.56[27]	na	na	na	na
Quetta	137.5[28]	0.67[29]	na	na	na	na
WHO[30]	70.00	0.50	10000.00	150	100	50

[11] Onursal B. and Gautam S.P., Vehicular Air Pollution - Experiences from Seven Latin American Urban Centers, 1997. Pg.19.

[12] Shah J.J., Nagpal T., and Brandon C., Urban Air Quality Management in Asia - Guidebook, 1997. Pg. 106.

[13] All figures for Karachi from : Brandon C., Valuing Environmental Costs in Pakistan: The Economy-wide Impact of Environmental Degradation, 1995.

[14] All figures for Lahore other than Pb and SO_2 are from: Punjab EPA - Mobile Laboratory Ambient Air Quality Data (Jun-Dec, 1996).

[15] Source: PCSIR, Lahore. Measurements taken 5 feet above ground level, December 1996.

[16] Source: Brandon C., Valuing Environmental Costs in Pakistan: The Economy-wide Impact of Environmental Degradation, 1995.

[17] PM10 and NO_2 figures for Islamabad from: EGC, Sectoral Study on Environmental Technology and Infrastructure:, 1998. Pg. 3-23. PM10 converted from TSP figures at the PM10/TSP ratio of 0.55.

[18] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.47. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[19] All figures for Peshawar other than Pb are from: Dijk I.A. and Hussein M.H., Environmental Profile of NWFP, 1994. Pg.50.

III. Quantifying Health Cost Estimates for Pakistan

Given the absence of studies that explore how the frequency of specific health outcomes vary with variations in ambient air pollution levels for developing countries, dose-response functions generated from studies in industrialised states are commonly used. Dose response functions in their simplest form take the following state:

$$dH_i = \beta\ POP_i * dA$$ [31]

Where:

dH_i = change in population risk of health effect (i)

β = slope of the dose response function

POP_i = population at risk of health effect (i)

dA = change in level of air pollutant under consideration.

---

[20] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.46. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[21] All figures for Faisalabad other than Pb are from: Punjab EPA - Mobile Laboratory Ambient Air Quality Data (Jun-Dec, 1996).

[22] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.49. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[23] All figures for Multan other than Pb are from: Punjab EPA - Mobile Laboratory Ambient Air Quality Data (Jun-Dec, 1996).

[24] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.49. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[25] All figures for Gujranwala other than Pb are from: Punjab EPA - Mobile Laboratory Ambient Air Quality Data (Jun-Dec, 1996).

[26] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.49. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[27] Ibid. The ambient air lead concentrations were estimated by Zaman et. Al. By utilising comparative Particulate Matter emission figures.

[28] Source: Gils H. and Baig M.S., Environmental Profile of Balochistan, 1992. Pg.26.

[29] Source: Zaman M.Q. and Martin R.P., Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis, 1999. Pg.49. The ambient air lead concentrations were estimated by Zaman et.al. by converting available blood lead level figures.

[30] Wijetilleke L. and Karunaratne R.A., Air Quality Management: Considerations for Developing Countries, 1993. Pg.63.

[31] Shah J.J., Nagpal T., and Brandon C., Urban Air Quality Management in Asia - Guidebook, 1997.

Shah et. al. (1997), state "in spite of ... caveats ... dose response functions are highly useful in estimating the health impact of pollution in developing countries. Dose response functions being estimated for developing countries, such as in Chile and India, have been shown to correspond well with those from industrialised countries". Table 2 presents an inventory of appropriate dose response functions.

Having established a method to calculate the severity of health impacts, the task arises to determine monetary values per unit of health impact. The impacts as described by the dose response functions can be divided into three broad categories.

i) Mortality
ii) Morbidity
iii) Restricted Activity Days

Mortality: To place a value on premature death we utilise a human capital approach. Such an approach values an individual's life according to the net present value of his/her productivity. The supposition elementary in this approach is that the worth of a person is based on what he produces which, in turn, is mirrored in his earnings. Cropper et al, 1997, estimate an average loss of 10 discounted productive years due to pollution in India. Applying the same figure for Pakistan, and using a GNP/capita value of $ 407.11 and a discount rate of 13.5 per cent we arrive at a value of US $ 2457.98 for premature death from air pollution. In the United States, values of a statistical life, obtained from willingness to pay studies, are typically much higher than those obtained by the human capital approach. In the absence of such studies for Pakistan the WTP estimates of the United States are projected to Pakistani data for obtaining an alternative estimate.

Morbidity: To value morbidity we use a cost-of-illness approach. This approach incorporates the direct costs of medical treatment. The costs of treatment can be obtained from local public and private health systems, or estimates based on the observed costs in other countries. For the purpose of this study both methods have been used, to provide alternative estimates of treatment costs. For local documentation, primary data on treatment costs has been collected from the following medical institutions in Lahore: i) Ganga Ram Hospital, ii) Adil Hospital, iii) Defence Hospital, and iv) Central Military Hospital. For an alternative appraisal, costs have been projected from United States figures by rectifying the costs downward by a factor equal to the ratio of average GNP per capita.

Restricted Activity Days: To arrive at a value for restricted activity days, income per person per day is calculated. For this purpose it is estimated that there are 250 working days annually. The figure obtained of $ 1.63, is the value per restricted activity day. For minor restricted activity days, half the value, i.e. $ 0.81 is utilised.

Table-2: Dose Response Functions

PM10	
Premature Mortality	Change in mortality = 0.096 * change in PM10 * 1/100 * crude mortality rate * exposed population
Respiratory Hospital Admissions	Change in respiratory hospital admissions per 100,000 = 1.20 * change in PM10
Emergency Room Visits	Change in emergency room visits per 100,000 = 23.54 * annual change in PM10
Restricted Activity Days	Change in restricted activity days per person per year = 0.0575 * change in PM10
Lower Respiratory Illness in Children	Change in bronchitis = 0.00169 * change in PM10
Asthma Attacks	Change in asthma attacks = 0.0326 * change in PM10
Respiratory Symptoms	Change in symptom days per person per year = 0.183 * change in annual PM10
Chronic Bronchitis	Change in chronic bronchitis = 0.0000612 * change in annual PM10
SO_2	
Premature Mortality	Percentage change in mortality = 0.048 * change in SO_2
Respiratory Symptoms	Change in probability of cough per 1000 kids per year = 0.0181 * change in SO_2
Chest Discomfort	Change in the probability of chest discomfort per year = 0.010 * change in SO_2

O_3	
Respiratory Hospital Admissions	Change in respiratory hospital admissions per person = 0.0077 * change in daily 1-hour max ozone (ppm)
Minor Restricted Activity Days	Minor restricted activity days per person per year = 34.0 * change in 1-hour max ozone (ppm)
Respiratory Symptoms	Change in symptom days per person per year = 54.75 * change in 1-hour max ozone (ppm)
Eye Irritation	Change in eye irritations per adult per year = change in 1-hour max ozone (ppm)
Asthma Exacerbation	Change in asthma attacks per year = 68.44 * change in 1-hour max ozone (ppm)
Pb	
Non-fatal Heart Attacks	Change in non fatal heart attacks per 1 million of males aged 40-59 = 340 * 1 $\mu g/m^3$ change in Pb.
Hypertension	Cases of hypertension per 1 million of males aged 20-70 = 72,600 * 1 $\mu g/m^3$ change in Pb.
Premature Mortality	Change in mortality per 1 million of males aged 40-59 = 350 * 1 $\mu g/m^3$ change in Pb.
IQ Loss	Loss of IQ points per child = 0.0975 * 1 $\mu g/m^3$ change in Pb.
NO_2	
Respiratory Symptoms	Change in respiratory symptoms per year = 10.22 * change in 1 hour max NO_2 (ppm)
CO	
Quantitative effects uncertain	

Source: *Ostro (1994).*

A significant detail that justifies reiteration is that such valuation endeavours only seize partial benefits. Studies to evaluate health effects of air pollution do not capture life style alterations or physical and psychological distrurbances that are subclinical in character, or other intangible effects.

Table-3: Health Cost Estimates for Pakistan

Measure	US Data[32]	Ratio of[33] GNP/capita	Pakistan Data		Unit
			Local Documentation	US Conversion	
Average Income					
Per year			407.11		US$ per year
Per day			1.63		US$ per day
Value of a statistical Life					
Human Capital Approach			2,457.98[34]		US$ per death
Compensating Wage Approach	3,000,000	0.175176		52,552.80	US$ per death
Respiratory Hospital Admissions	6,306	0.175176	55.56	110.47	US$ per case
Emergency Room Visits	178	0.175176	8.89	3.12	US$ per case
Restricted Activity Days			1.63		US$ per day
Minor Restricted Activity Days			0.81		US$ per day
Respiratory Symptoms	5.35	0.175176	0.89	0.09	US$ per day
Lower Respiratory Illness in Children	5.32	0.175176	0.89	0.09	US$ per case
Asthma Attacks	29.84	0.175176	6.00	0.52	US$ per case
Asthma Exacerbation	29.84	0.175176	6.00	0.52	US$ per case
Chronic Bronchitis	132	0.175176	13.33	2.31	US$ per case
Chest Discomfort	5.97	0.175176	1.67	0.10	US$ per case
Eye Irritation	5.97	0.175176	0.89	0.10	US$ per case
Non-fatal Heart Attacks	28,334	0.175176	333.33	496.34	US$ per case
Hypertension	442	0.175176	20.00	7.74	US$ per case
IQ Loss	1,147	0.175176		20.09	US$ per point

[32] Source for US Data: Shah J.J., Nagpal T., and Brandon C., Urban Air Quality Management in Asia - Guidebook. 1997.Pg.46.

[33] Based on: US GDP/capita = $ 23,240, Pakistan GDP/capita = $ 407.11. Source for US GDP/capita: Shah J.J., Nagpal T., and Brandon C., Urban Air Quality Management in Asia - Guidebook. Source for Pakistan GDP/capita: Pakistan Economic Survey 1998 figure of Rs. 18,320 converted at official exchange rate of 45 Rs./$.

[34] Net Present Value of GDP/capita discounted by interest rate @ 0.135 for a period of 10 years.

Applying the health cost estimates computed in Table-3, and the dose response functions stated in Table-2, to ambient air concentrations previously tabulated, annual pollutant cost estimates are tallied for the nine major urban cities of Pakistan.

The results obtained for annual health cost estimates for the ten most populous cities of Pakistan due to air pollution are summarised in Table-4. Computed figures show more than 4300 premature deaths per year and over 925 million annual illnesses, an economic valuation of which suggests a monetary estimate of between \$ 583 million and \$ 1,121 million. As seen, Karachi and Lahore make up a massive proportion of the total costs. As populations decrease it is observed that the annual health costs of cities decline swiftly. So much so in fact that the proportion of costs of the last two cities (Peshawar and Quetta) is negligible. In the absence of any pollution emission figures at all for the rest of Pakistan, it is very difficult to estimate health cost values for the rest of the country. It is expected however that since the adverse effects of air pollutant emissions are concentrated in the larger cities of the country, therefore the non-computation of costs for Pakistan's remaining cities will not lead to a consequential discrepancy in the total cost figure for the country. PM10 is seen to be responsible for over seventy five percent of the health impact damages in the country. Almost all premature deaths attributable to air pollution are observed to accrue from PM10. Lead contributes to much of the rest of the damages. Of great concern is the resulting loss in intellectual capacity. Karachi and Lahore are seen to account for an estimated combined loss of 2.5 million points annually.

Table-4: Annual Health Cost

City	Annual Health Costs		Annual Health Costs Due to Vehicles[35]	
	Local Data	US Data	Local Data	US Data
Karachi	399.78	216.76	109.45	69.79
Lahore	314.53	159.93	56.78	33.16
Faisalabad	145.16	72.60	24.31	13.56
Rwp. & Ibd.	52.31	27.63	11.92	7.74
Multan	127.11	62.80	19.63	10.37
Hyderabad	2.43	2.04	2.19	1.84
Gujranwala	63.33	32.12	11.57	6.79
Peshawar	4.11	3.45	3.70	3.11
Quetta	12.52	6.28	2.13	1.19
Total:	1,121.28	583.61	241.68	147.55

[35] Calculated based on the following percentages for vehicular emissions out of total emissions: SO_2 - 4.47% (Murtaza N., 1991), PM10 - 13.9% (Wijetilleke L. et al, 1993), Pb-90% (Walsh M. et al, 1997), NO_x - 48.9% (Wijetilleke L. et al, 1993)

VI. Costs of Reducing Pollutant Emissions

Several pollutant reducing procedures are described in literature, and have been adopted by different countries. For the purpose of this study the most cost effective and practical techniques of these are evaluated for Pakistan's scenario. The costs of reducing the pollutants discussed are borne through three major procedures. First, the phasing out of lead from gasoline requires modifications in refinery specifications and a per liter addition of an octane raising substitute. Second, the reduction in the sulfur content of diesel fuel requires the building of capacity for hydrodesulfurisation of oil products. Third, the application of catalytic converters requires an extra purchasing cost.

i) Phasing out Lead from Gasoline: The costs of this procedure can be traced to two capital orgins. First, the current refinery specifications in the country require modifications which obligate a fixed cost investment. Second, the input of an octane raising substitute induces a per liter increment in cost.

Refinery Construction and Modification Costs: New construction and modifications to existing refinery plants are expected in order to produce the specified unleaded gasoline while retaining existing performance levels. This represents an additional cost which must again be weighed against the potential benefits associated with reductions in the lead content of gasoline in Pakistan. Industry sources suggest the installation of light naphtha isomerisation units, installation of feed preparation light naphtha hydrotreating units, and the reform of existing reformer units for the purpose. Zaman et al (1999), quote the construction and modification costs for Pakistan's three oil refineries, to be approximately 4,171 million rupees, for a reduction in lead levels from an average of 0.63 g/l to 0.15 g/l. Assuming a linear increase in costs for a further reduction in lead, the cost for total phase out is estimated at approximately 5,474 million rupees ($ 121.64 million).

Losses in Consumer Surplus: Switching from the production of highly leaded to unleaded gasoline will push up the price of gasoline, detrimentally affecting consumers. Working with petroleum industry cost estimates, it is estimated that removing the lead content of gasoline while maintaining current octane levels would increase petroleum production costs by 0.2953 rupees per liter.[36] The loss in consumer surplus associated with

[36] Zaman et al (1999) quote an incremental increase of Rs. 0.225 per liter for a reduction of lead in gasoline from 0.63 g/l to 0.15/l. Assuming a linear increase in costs a value of Rs. 0.2953 is calculated for a total phase out.

this cost increase may be estimated with reference to the following demand function for gasoline in Pakistan:

$$\mathbf{Q_d = .572310000 - 53173000\,P + 63.33\,V + 324760\,Y}$$

t-stats (-0.562) (-1.371) (1.471) (2.150)

$$\mathbf{R^2 = 0.89, \; d = 1.6}$$

Where

Q_d is the quantity of gasoline demanded

P is the real 1987 price of gasoline per liter

V is the number of vehicles in Pakistan

Y is real 1987 per capita income

Keeping the aggregate of vehicles and per capita income consistent at present day levels, the above mentioned modification in price results in a 5,610,924 liter reduction in demand for gasoline and a loss in consumer surplus of 395,924,383 rupees in present terms.[37]

Effectiveness: 90 per cent of all lead emissions in urban areas are estimated to be attributable to traffic.[38] Hence 90 per cent of the adverse health effects occurring from lead emissions have traffic as their primary source. By totally removing lead from gasoline, 90 per cent of adverse health effects, and 100 per cent of adverse health effects due to automobile pollution are expectedly eliminated.

ii) Reduction in the Sulfur Content of Diesel: Supplementary construction and alterations to present refinery plants are anticipated in order to generate the specified reduction in sulfur content while maintaining standing performance guidelines. This presents an auxiliary cost which must once more be weighed against the associated potential benefits. Industry sources recommend the installation of HSD hydro desulfurisation units for the purpose. Refinery quoted costs for the installation of these units amount to a combined total of Rs. 5,882 million ($ 130.71 million) for a reduction in weight percent of sulfur content in diesel from 1.0 per cent to 0.2 per cent.[39]

---

[37] Present day vehicles: 2.083,668. GDP Deflator : 2.7984675. Income: Rs. 18,320. Real Income: Rs. 6546.44.

[38] Walsh M., Shah J.J., Clean Fuels for Asia: Technical Options for Moving Toward Unleaded Gasoline and Low Sulfur Diesel, 1997. Pg.8.

[39] Government of Pakistan, Report on Introduction of Environment Friendly Clean Fuels in the Country, 1996.

Effectiveness: Najeeb Murtaza (1991), estimates that approximately 4.47 per cent of SO_2 emissions in Pakistan emanate from the transport sector. By removing 80 per cent of the sulfur content in diesel, it is estimated hence that 3.58 per cent of all adverse health effects occurring due to SO_2, and 80 per cent of adverse health effects occurring due to automobile pollution are eliminated. Additionally sulfur also exhibits particulate forming tendencies. Shah J.J. et al (1997) state that roughly 1.2 pounds of particulate is formed per pound of SO_2. Tariq N. et al (1985) estimate that Lahore has SO_2 emissions of 1,377 tonnes due to motor vehicles, and particulate emissions of 2,014 tonnes due to motor vehicles. Computing from the fact that 80 per cent of sulfur content in diesel will be removed, it is estimated that emissions in Lahore due to motor vehicles will reduce by 1101.6 tonnes. Applying the ratio established by Shah J.J. et al (1997), that leads to a reduction of 1321.9 tonnes (i.e. 65.64 per cent) of particulate emissions, it is estimated that approximately 13.9 per cent of all annual world PM emissions are attributable to the transport sector.[40] Hence it is approximated that 9.12 per cent of all adverse health effects for PM, and 65.64 per cent of adverse effects due to automobile pollution for PM will be reduced by the stated reduction in sulfur content of diesel.

iii) Application of Catalytic Converters: Tail pipe emissions of CO, NO_x and various organic compounds are addressed through the application of catalytic converters. These can lead up to a 90 per cent reduction in emissions.[41] Wijetilleke et al (1993), estimate through a survey of twenty-one countries that 69.8 per cent of all CO emissions and 48.9 per cent of all NO_x emissions are attributable to transport. Hence the utilisation of catalytic converters is expected to lead to corresponding 62.8 per cent and 44 per cent reduction respectively in adverse health effects. Extra purchasing costs of vehicles equipped with such a device are estimated at US $ 200 per unit by Shah J.J. et al (1997). Naim P. (1996) meanwhile describes the development of a low cost catalytic converter by students of the NED University of Engineering and Technology, Karachi. Making this commercially available could be a possibility. Considering however the low level of NO_x pollution in the country, and the unavailability of quantitative effects associated with CO, the application of catalytic converters is not considered for the purpose of the cost-benefit analysis in this study.

---

[40] Wijetilleke L. and Karunaratne R.A., Air Quality Management: Considerations for Developing Countries, 1993. Pg.65.

[41] Shah J.J., Nagpal T., and Brandon C., Urban Air Quality Management in Asia - Guidebook, 1997. Pg.56.

V. Results

In this section the results of the study are presented. Consumer benefits from cutbacks in pollutant emissions are determined and exhibited. Then each of the costs and benefits discussed in previous sections are combined to arrive at an overall benefit-cost ratio for proposed policy switches. The section is completed with a sensitivity analysis of the results obtained.

Benefits: The population will gain from reduction in pollutant emissions through the application of the procedures described in the previous section. 90 per cent of all adverse health effects due to lead emissions, 9.12 per cent of those due to PM10 emissions, and 3.58 per cent of those due to SO_2 emissions shall be eliminated. Benefit figures for each city based on these percentages are calculated and presented in Table-5.

Table-5: Annual Benefits Through the Reduction in Pollutant Emissions in Pakistan ($ '000,000)

City	PM10	PM10	SO_2	SO_2	Pb	Pb
	Local Data	US Conversion	Local Data	US Conversion	Local Data	US Conversion
Karachi	28.23	13.75	0.28	0.40	56.39	47.35
Lahore	27.05	13.17	0.02	0.04	17.25	14.49
Rwp. & Ibd.	4.21	2.05	-	-	5.49	4.62
Peshawar	-	-	-	-	3.70	3.11
Faisalabad	12.74	6.21	-	-	4.88	4.10
Multan	11.36	5.53	-	-	2.32	1.95
Gujranwala	5.44	2.65	-	-	3.27	2.75
Hyderabad	-	-	-	-	2.19	1.84
Quetta	1.09	0.53	-	-	0.46	0.38
Total:	90.12	43.89	0.30	0.44	95.95	80.59

Summing health benefits yields total annual benefits from the proposed policies of $ 124.92 million and $ 186.37 million respectively for the two approaches used (local data and US conversion). Assuming a 13.5 per cent discount rate and an infinite time horizon, the present value of these annual benefits is $ 925.3 - $ 1380.52 million.

Costs: The costs of the proposed policies fall into two categories: annual losses in consumers' surplus as a result of higher gasoline prices, and initial refinery construction and modification costs. Annual losses in consumers' surplus were found to equal $ 8,798,320. Assuming, once again, a discount rate of 13.5 per cent, the net present value of the annual loss in consumers' surplus equals $ 65,172,740. One-time refinery construction and modification costs were found to equal 252.35 million dollars. The net present value of total costs thus equals $ 317.5227 million.

Benefit-Cost Analysis: The benefit-cost ratio for the proposal is found by dividing the NPV of total benefits by the NPV of total costs. Doing this we find a B/C ratio of 2.91 for US converted data (benefits outweigh costs by 2.91 to 1), and a ratio of 4.35 for locally documented data (benefits outweigh costs by 4.35 to 1). IRR values are found to be 46.01 per cent and 70.36 per cent respectively. With positive values associated to NPV and the B/C ratio, in addition to an IRR value greater than the cost of capital, the adoption of the proposed pollutant reducing policies is strongly recommended. Calculations are summarised in Table-6.

Table-6: Summary of Policy Analysis

	Using Local Data	Using US Converted Data
Net Present Value of Benefits (million dollars)	1380.5190	925.3333
Net Present Value of Costs (million dollars)	(317.5227)	(317.5227)
Cumulative Net Present Value (million dollars)	1062.9960	607.8106
Benefit-Cost Ratio	4.347778	2.914227
IRR	70.36 %	46.01 %

VI. Conclusions and Recommendations

i) Most consequentially (and most clearly) we find that the economic benefits of removing the lead content of gasoline, and reducing the sulfur content of diesel outweigh the associated costs. We thus conclude that the policies, or offshoots of them, should by all means be executed. It is however observed that the benefits accruing are not uniformly distributed.

ii) By far the greatest automobile related pollution, and therefore the greatest damage occurs in Karachi and Lahore, followed by Faisalabad, Gujranwala, and Multan. Automobile pollution damages in Quetta, Peshawar and other smaller cities are essentially nonexistent as automobile traffic and therefore ambient air pollutant levels are relatively low. In these smaller cities, the costs associated with the removal of lead from gasoline will likely exceed the benefits. It is therefore recommended that a flexible programme to restrict the sale of leaded gasoline and high sulfur content diesel in major urban areas such as the cities identified above, be implemented.

iii) It is suggested that the government provide market incentives to producers for the lead phase out and sulfur reduction approaches. Since the petroleum sector is already heavily taxed it may be constructive for example to reduce the level of development surcharge currently levied.

iv) Since this study had certain unavoidable limitations with regard to data, it is suggested as a final recommendation that work be expanded in collecting up-to-date pollution emission data for the cities examined and for those not examined by this study.

References

Biswas D, 1997. Improvement of Fuel Quality and Related Initiatives for Air Pollution Control: Indian Experience, Central Pollution Control Board, Delhi.

Brandon C., 'Valuing Environmental Costs in Pakistan: The Economy-Wide Impact of Environmental Degradation', The World Bank, 1995.

Dorfman R & Dorfman S.N., Economics of the Environment: Selected Readings.

EGC, 'Sectoral Study on Environmental Technology and Infrastructure', Engineering General Consultants, 1998.

EIP, 'Automobile Industry', Industrial Research Service Report No. 664, EIP, September 20, 1995.

Faiz A., Weaver S. C. & Walsh P. M., 'Air Pollution from Motor Vehicles-Standards and Technologies for Controlling Emissions', The World Bank, 1996.

Government of Pakistan, 1998 Census Report of Pakistan: Preliminary Data, Population Census Organisation, Statistics Division, Government of Pakistan, Islamabad, 1998.

Government of Pakistan, *Pakistan Economic Survey, 1997-98,* Government of Pakistan, Islamabad, 1997.

Government of Pakistan, *Pakistan Energy Yearbook 1997,* Government of Pakistan, Islamabad, 1997.

Haroon H., 'Draft Recommendations of the Pakistan Environmental Protection Council's Committee on Clean Fuels', Clean Fuels Workshop, 1995.

Hertzman C., 'Environment and Health in Central and Eastern Europe', The World Bank, 1996.

IUCN, Environmental Profile of Pakistan, The World Conservation Union (Pakistan), 1989.

Jamal Q.M., 'Pakistan Refinery Limited: Draft Report on Environment Friendly Fuels', Facsimile Transmission to Farooq R., Director (Refining), Ministry of Petroleum and Natural Resources, August, 1996.

Kazmi S.H., 'Effects of Furnace Oil Surcharge on the Power Tariff', *Pakistan and Gulf Economist,* September, 1997.

Lester B. L., Eugene P.S., Air Pollution and Human Health, Economics of the Environment: Selected Readings.

Lovei M., 'Phasing Out Lead from Gasoline in Central and Eastern Europe-Health Issues, Feasibility and Policies', The World Bank, 1997.

Munir T., Murtaza S.A. Iqbal S.F., Shah S.F.E., Jamali H.A., 'Petroleum Pricing Policy in Pakistan: An Investigation into Tariff Structure and Competitiveness', Senior Project, Lahore University of Management Sciences, 1998.

Murtaza N., 'Environmental Profile of Pakistan', OECD, 1991.

Naim P., 'Take a deep breath', IUCN, 1996.

OECD, 'Environmental Effects of Automotive Transport', The OECD Compass Project 1986.

Onursal B., Gautam S.P., 'Vehicular Air Pollution: Experiences from Seven Latin American Urban Centers', The World Bank, 1997.

PEPC, 'Report on Introduction of Environment Friendly Clean Fuels in the Country', PEPC, Islamabad, 1996.

Sayeg P., 'Draft Report on Thailand Unleaded Fuels Strategy Review', The World Bank, 1997.

Shah J.J., Nagpal T., and Brandon C., 'Urban Air Quality Management in Asia - Guidebook'. The World Bank, 1997.

Walsh M. & Shah J.J., 'Clean Fuels for Asia: Technical Options for Moving toward Unleaded Gasoline and Low-Sulphur Diesel', The World Bank, 1997.

Wijetilleke L & Karunaratne R.A., 'Air Quality Management: Considerations for Developing Countries', The World Bank, 1993.

Zaman M.Q. and Martin R.P., 'Phasing out Lead from Gasoline in Pakistan: A Benefit-Cost Analysis', CMER, Lahore University of Management Sciences, 1999.