A Health Economic Cost/Benefit Analysis of Reducing Lead Emissions from Motor Vehicles in Bangladesh

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1. Key Findings and Recommendation

Reducing lead emissions from motor vehicles in Bangladesh will have very significant net social benefits in all the cost/benefit scenarios examined. The benefits resulting from improved health status of children (6 year old) in Dhaka alone is estimated to be in the range of US$30-100 million per year. Cost-effective policy options that could be readily implemented to reduce lead emissions exist. It is recommended that these options be examined to identify the most appropriate one for immediate implementation.

2. Background

Several recent studies have shown that airborne lead levels in Dhaka are among the highest in the world. The Health Economics Unit (HEU) has conducted a study entitled "Health and Technical Analysis of Options for Reducing Lead Emissions From Motor Vehicles in Bangladesh"[2] (the "Study") to examine how these high airborne levels of lead are resulting in high levels of lead concentration in the blood of Dhaka residents with damaging health effects, and what options there are to reduce lead emissions from motor vehicles which is a major source of lead emission into the atmosphere. One aspect of this Study attempts to provide a cost/benefit analysis of lead emission reduction. This research paper presents the key findings from this aspect of the Study.

3. Current Lead Situation in Bangladesh

Results from the HEU Study suggest that there is a lead crisis at present in Bangladesh. Based on a non-random cross-section blood test sample[3] of Dhaka residents obtained for the Study, the average level of lead found is about 50 microgram per decilitre (μg/dL), roughly five times higher than the "level of concern" established by the Center for Disease Control in the United States. In fact, detrimental health effects from lead in children have been detected at concentrations as low as 5 μg/dL. As the Study's blood samples were collected during the wet season when air lead levels are relatively low, the measured average of 50 μg/dL of these samples is likely to be an under-estimation of the year round average.

These blood lead levels are very high and are cause for serious concern. A review of international literature has not found any comparable blood lead levels in other countries. The average lead level in residents of cities around the world that have removed lead from gasoline, which is a major source of lead emission, is below 5 μg/dL. This crisis situation in Bangladesh, however, can be effectively addressed by eliminating the use of lead (for purposes of increasing octane ratings in automobile fuel) through determined policy actions. These policy actions, and their corresponding

[1] This is a summary of the key cost-benefit findings, from the health economics perspective, of the Health Economics Unit's Research Paper Number 11A.

[2] HEU Research Paper Number 11A.

[3] Given its small sample size (40) the results could not be easily generalised, and hence must be treated as a case study. However, its results are so completely consistent with findings from all the available studies of airborne lead levels in Dhaka that (i) they deserve to be taken seriously, and (ii) they constitute a compelling justification for the determined pursuit of further investigation of this situation.

economic costs and benefits, are assessed and summarised in the next four sections.

4. The Cost/Benefit Analysis Methodology

The methodology employed to conduct a cost/benefit analysis of reducing lead emissions can be briefly described as follows:

[A] Assessment of the economic benefit of reducing lead emissions, which in turn entails the following steps:

(i) identify the damaging health effects as a result of high blood lead levels in a particular population;
(ii) evaluate the economic costs of these damaging health effects associated with that particular population; and treat these costs as the amount of economic benefit that can be expected from reducing lead emissions;
(iii) estimate the vehicle-related costs of using leaded fuel and treat them as additional economic benefits (as these costs are eliminated by using unleaded fuel) that can be expected from reducing lead emissions.

[B] Assessment of economic cost of reducing lead emissions, which in turn entails the following steps:

(i) estimate the incremental costs of switching to production of unleaded fuel, taking into account the current situation and capacity at the Eastern Refinery which is the only refinery in Bangladesh (two options are identified);
(ii) estimate the vehicle-related benefits of using leaded fuel and treat them as additional costs (as these benefits are eliminated by switching to unleaded fuel) that can be expected from reducing lead emissions.

5. Estimation of the Economic Benefits of Reducing Lead Emissions

Following the steps outlined above, the estimations of economic benefits of reducing lead emissions are summarised as follows.

5.1 *Identifying the Health Effects due to Lead Toxicity*

The absorption of lead from air takes place via inhalation[4]. Small lead particles (less than 0.5 μm in diameter) are usually borne by ambient air and, when inhaled, are deeply embedded in lungs. Once lead is absorbed, it quickly moves to blood and other soft tissues such as liver and kidneys. This is followed by a slower distribution into bone, teeth, and hair. The effects of lead on human health include the biochemical effects, impacts on the haematopoietic system, the nervous system, the renal system, the cardiovascular system, the gastrointestinal system, and effects on liver, bone, reproduction. The health impacts of lead toxicity are therefore widespread, and could be fatal.

From the society's point of view, one impact is particularly harmful – permanent reduction in brain development in children. While children share with adults all the health effects of lead toxicity, they suffer additionally from potentially serious effects of reduced mental and cognitive capabilities as measured in IQ scores, with life long consequences.

Estimating the economic costs of all these health effects is simply not possible due to data deficiency and time and resource constraints. Accordingly, the monetary value of blood lead reduction of a single category of health impact is estimated in this Study – IQ impacts in children as

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[4] Lead can also be absorbed through lead contaminated drinking water and contact with soil. Thus Dhaka residents living in areas of high automobile lead emissions may be exposed to lead in pathways other than inhalation.

measured by changes in lifetime earnings.[5]

5.2 *Evaluating the Costs of IQ Impacts on Children*

Based on a review of the research literature, a set of key assumptions have been formulated for evaluating the costs of IQ impacts on children as a result of lead toxicity. These assumptions are described as follows:

(i) Only the six-year-old children are included in the estimate as (a) they are most at risk, and (b) they are the most studied group in terms of establishing the relationship between lead levels and change in IQ.

(ii) The research literature indicates a relationship between 0.245 IQ points per 1µg/dL change in blood lead concentration. This Study adopts a conservative approach and assumes that only half of this value (0.123 IQ points per 1 µg/dL).

(iii) Two scenarios are developed for estimating the reduction of airborne lead as a result of reducing automobile lead emissions. The first scenario, the "Low Benefit Case", assumes that the elimination of lead in fuel will result in a 25 µg/dL reduction in average blood lead content of affected citizens (from 50 µg/dL to 25 µg/dL). It is thus a "conservative" scenario. The second scenario, the "High Benefit Case," assumes the reduction to be higher at 40 µg/dL (from 50 to 10 µg/dL). It is thus a more "optimistic" scenario.

(iv) The life time earning of a six-year-old Dhaka child is calculated assuming: (1) Dhaka's average wage level is four times that of the country average, with a per capita GDP of US$250; (2) wages grow at a real rate of 1% per year; (3) a 5% discount rate is used for calculating the present value of the stream of life time earning, (4) a one point change in IQ will result in a 0.9% change in life time earnings, taking into account both the wage and employment effects; (5) the total number of six-year-old is estimated to be 6.25% (1/16) of those under sixteen years old, which in turn accounts for about 40% of Dhaka's 9 million resident; (6) only one-third of these six-year-old are assumed to be affected by high levels of airborne lead in the "Low Benefit Case", and two-thirds of these six-year old are assumed to be affected in the "High Benefit Case".

Table 1 below summarises the calculations of the monetary benefits of reducing lead emissions (in 1997 US$).[6]

[5] One advantage of choosing to estimate the monetary value of this category of health effect, apart from its obvious importance to the society, is that there are several similar studies with well tested methodologies and assumptions.

[6] From Table 7.4 of the HEU Research Paper Number 12A.

Table 1. Estimations of the Health Benefit of Reducing Lead Emission

Assumptions and Inputs	Low Benefit Case	High Benefit Case
Dhaka resident's discounted life time earnings (5% real rate of discount)	$15,120	$15,120
Change in IQ points per µg/dL change in Blood lead levels	0.123	0.123
Percentage change in earnings per IQ point	0.9%	0.9%
Average change in blood lead levels after eliminating lead in automobile fuel	25 µg/dL	40 µg/dL
Resultant change in IQ points in six-year-olds	3.1	4.9
Percentage change in expected earnings	2.7%	4.4%
Total change in Dhaka resident's expected life time earnings	$415	$665
Total number of six-year-olds in Dhaka	225,000	225,000
Total Number of six-year-olds affected	74,250 (33%)	148,300 (66%)
Increased earnings from eliminating lead in automobile fuel	$30.8 million	$98.8 million
Increased earnings per litre of fuel (at 189 million litres consumed, 1995-96)	16.3 cent (US)	52.3 cents (US)

5.3 *Evaluating Vehicle-Related Benefits from Reducing Lead Emissions*

There are two key vehicle-related benefits from switching to unleaded fuel. They are (i) the benefits from reduced wear and tear to spark plugs and fuel oil from unleaded fuel; and (ii) the benefits from better fuel efficiency running on unleaded fuel. Their respective monetary values are estimated as follows.

(i) Table 2 below summarises the assumptions and methodology used in evaluating the benefits from reduced wear and tear to spark plugs and fuel oil from switching to unleaded fuel. The assumed savings are based on US data but adjusted for lower labour costs, but higher costs of spare parts. The total adjustment is 1/3 lower in the High Benefit Case, and ½ lower in the Low Benefit Case.

Table 2. Benefit Calculation of Engine Maintenance from Unleaded Fuel (1997 US$)

Assumptions and Inputs	Low Benefit Case	High Benefit Case
Savings per vehicle per year (4 wheel)	$12.22	$16.28
Savings per vehicle per year (2 & 3 wheel)	$6.11	$8.14
Total no. of 4-wheel vehicles in 1996	110,000	110,000
Total no. Of 2 & 3 wheel vehicles in 1996	150,000	150,000
Total savings per year	$2.26 million	$3.01 million
Savings per litre (at 189 million litres petrol consumed, 1995-6)	1.2 cents (US)	1.59 cents (US)

(ii) Table 3 below summarises the assumptions and results of the estimated fuel economy benefits from using unleaded fuel. The assumed values are based on actual estimated values in both road and laboratory tests reviewed and conducted by the Environmental Protection Agency of the Government of the United States. The low and high benefit cases differ in the assumptions adopting the low and high ends of the range of estimations regarding reduction in fuel use.

Table 3. Benefit Calculation of Fuel Economy from Unleaded Fuel (1997 US$)

Assumptions and Inputs	Low Benefit Case	High Benefit Case
Percentage reduction in fuel use	2.0%	4.0%
Fuel cost per litre (ex. tax)	$0.25	$0.25
Savings per litre (at 189 million litres petrol consumed, 1995-6)	0.5 cents (US)	1.0 cents (US)

6. Estimations of the Economic Costs of Reducing Lead Emissions

Two major categories of costs are associated with reducing lead emissions. The first is the incremental costs of retrofitting the Eastern Refinery so that unleaded fuel can be produced. The second is vehicle-related costs due to the use of unleaded fuel. These incremental costs are estimated with the assumption that the Eastern Refinery has to expand its output due to rapidly rising demand. Option one then is to expand and retrofit its capacity to produce unleaded fuel. Option two is to expand very substantially the amount of imported unleaded fuel to blend with the leaded fuel currently being produced to achieve a virtually unleaded product.

6.1 *Estimations of the Incremental Costs of Refinery Upgrade*

To produce unleaded fuel, it will require construction of a reformer with about twice the capacity rather than just expanding the current capacity to continue to produce leaded fuel. Thus, for the larger reformer, half of the cost can be considered incremental over the cost of a smaller reformer for leaded-only fuel. In addition, one hundred percent of the cost of an isomerization unit would be considered incremental as it would not be necessary in an upgrade to produce only leaded fuel. Based on extensive consultations with knowledgeable professionals and managers in Bangladesh and internationally, a range of cost estimates have been developed. Two cost scenarios are developed accordingly, using the high and low ends of the estimates, to estimate the incremental cost of refinery upgrade to produce unleaded fuel. The capital costs are amortised over 10 years, and a 7% real rate of interest is assumed. Capital costs of between US$20 million and US$25 million for the reformer and between US$40 million and US$50 million for the isomerization unit are estimated. Operating costs of between US$6 and US$8 per ton are assumed per unit. The cost of lead is assumed to be between US$7,500 and US$10,000 per ton (treated as a saving). These estimates are summarised in Table 4 below.

Table 4. Refinery Upgrade Cost Estimations (1997 US$)

Cost Scenarios	Capital Costs Annual (Million $)	Operating Costs US Cent/ Litre	Total Incremental Cost US Cent/ Litre
Low Cost:			
Reformer	2.59	0.42	
Isomerization Unit	5.18	0.42	
Total Incremental Cost			0.88
High Cost:			
Reformer	3.89	0.56	
Isomerization Unit	7.77	0.56	
Total Incremental Cost			1.89

6.2 *Using Imported Blends to Achieve Completely Unleaded Fuel*[7]

Given the current rates of growth in demand, the ratio of blend stock to the local refinery produced fuel will be about 2:1. Thus, the incremental cost of producing unleaded fuel in this option is the cost difference between importing the blends necessary to produce unleaded fuel and importing other blends that do not produce unleaded fuel. The difference is estimated at about US$5 – US$6 per barrel of blend cost, or US$3 to US$4 per barrel of final product, minus the avoided lead cost of about US$1.5 to US$2 per barrel. This translates to about 0.6 to 1.6 cents (US) per litre, somewhat lower than the costs estimated under the refinery upgrade scenario.

6.3 *Vehicle-Related Costs*

Given that lead acts as a lubricant on piston valve seats, non-hardened valve seats in older models may deteriorate with this lubricant. Most vehicles built after 1970, and virtually all vehicles built since 1980 have hardened valve seats, which prevent this problem. For vehicles without hardened valve seats, problems arise with unleaded fuel only when they are driven regularly at high speeds exceeding 100 km/hour.

There are very few pre-1980 vehicles in Bangladesh that are driven regularly at speeds exceeding 100km/hour. Accordingly, the percentage of affected vehicles is estimated to be less than 1% in the high cost case, and less than 0.1% in the low cost case. The cost to vehicles in the United States with affected valve seats was estimated by the Environmental Protection Agency to be 1 cent per kilometre. This estimate has been lowered for Bangladesh due to the lower costs of auto repair – lowered by 1/3 in the high cost case, and ½ in the low cost case. The resultant estimates are 0.0114 cents (US) per litre in the high cost case, and 0.0009 cents (US) per litre in the low cost case.

[7] This option will produce unleaded fuel with a slightly lower Research Octane Number (RON), which does not have any impacts on vehicle performance, however.

7. Summary of Costs and Benefits of Reducing Lead Emissions

The different categories of benefits and costs of reducing lead emissions are summarised in Table 5 below. It should be noted that the benefits are very conservatively estimated. For example, the health benefits are estimated for only one category of a very wide range of health benefits (which has been assessed as less than one-third of the total potential benefits), and non-lead air quality improvement as a result of using unleaded fuel has not been included in the estimates. Whereas the cost estimates tend to be "conservative" on the high side.

In Table 5, two cost/benefit cases are summarised as "boundary cases." They are the high cost and low benefit case, which represents the worse case scenario; and the low cost and high benefit case, which represents the best case scenario. As shown below, the net benefits are very substantial in both cases, demonstrating that reducing lead emissions in Bangladesh could be very beneficial from the point of view of health and other related effects.

Table 5. Summary of Costs and Benefits of Reducing Lead Emissions

Cost/Benefit Categories	High Cost & Low Benefit Case	Low Cost & High Benefit Case
1. Health Benefits:		
a. 6 year old life time earnings	16.3 cents/litre	52.3 cents/litre
b. Other health benefits	not estimated	not estimated
c. Non-lead air quality	not estimated	not estimated
2. Vehicle-Related Benefits:		
a. Reduced engine wear	1.2 cents/litre	1.59 cents/litre
b. Fuel efficiency	0.5 cent/litre	1.0 cent/litre
3. Refining Option Costs		
a. Reformer unit	(0.76) cent/litre	(0.52) cent/litre
b. Isomer Unit	(2.13) cents/litre	(1.69) cent/litre
c. Lead elimination savings	1.0 cent/litre	1.34 cents/litre
4. Imported Blends Option	1.6 cents/litre	0.6 cent/litre
5. Vehicle-Related Cost	0.01cent/litre	0.001 cent/litre
6. Total Benefit	18.0 cents/litre	54.89 cents/litre
7. Total Cost (Refining Option)	1.9 cents/litre	0.871 cent/litre
8. Total Cost (Import Option)	1.61 cents/litre	0.601 cent/litre
9. Net Benefit		
a. Refining Option	**16.1 cents/litre**	**54.019 cents/litre**
b. Import Option	**16.39 cents/litre**	**54.289 cents/litre**

These per unit net benefits can be expressed in terms of annual totals, both for the 1995-96 period, and projected to year 2000 assuming a 10% per year growth of fuel consumption. Another assumption used to project the annual net benefits at year 2000 is that the number of 6 year old in Dhaka then will be the same as it is today - a very conservative assumption that is likely to render the estimation of net benefit to be lower than the actual. They are summarised in Table 6.

Table 6. Annual Net Benefits

	High Cost & Low Benefit Case	Low Cost & High Benefit Case
1995-96 Period (189 million litres)		
Refining Option	**US$30.43 million**	**US$102.1 million**
Import Option	**US$30.98 million**	**US$102.6 million**
Net Non-Health Benefit (1995-96)		
Refining Option	(-0.2 cents/litre)	1.72 cents/litre
Import Option	0.09 cents/lire	1.99 cents/litre
Total Fuel Consumption in 2000 (at 10% growth per year)	304.3 million litres	304.3 million litres
Net Non-Health Benefit (2000)		
Refining Option	(US$-0.61million)	US$5.2 million
Import Option	US$0.27 million	US$6.1 million
Total Net Benefit (2000)		
Refining Option	**US$30.19 million**	**US$104 million**
Import Option	**US$31.07 million**	**US$105 million**

8. Conclusions

These conservative estimates demonstrate the considerable economic and health benefits that could be realised from reducing lead emissions from motor vehicles in Bangladesh. Accordingly, the HEU recommends that GOB considers the pursuance of one of the options to realise these benefits.