LEAD POLLUTION IN DHAKA CITY

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Abbreviations

CH_4	Methane
CNG	Compressed natural gas
CNS	Central Nervous System
CO	Carbon monoxide
CO_2	Carbon dioxide
DOE	Department of Environment
HC	Hydrocarbons
IPCC	UN Intergovernmental Panel on Climate Change
LPG	Liquefied petroleum gas
N_2O	Nitrous Oxide
NMHC	Non-methane hydrocarbon
NO_x	Oxides of Nitrogen
PM_{10}	Particulate matter less than 10 microns in diameter
Pb	Lead
PbB	Blood lead levels
SO_2	Sulfur Dioxide
SPM	Suspended Particulate Matters
TSEV	Two-stroke engine vehicles
WHO	World Health Organization
TEL	Tetraethyl lead
TML	Tertramethyl lead

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Introduction

Lead pollution is a serious problem in Dhaka city affecting thousands of men, women and children. Several misconceptions by the media and public of the sources of lead emissions delay resolving the problem. These misconceptiens need to be corrected and the real sources and effects of lead pollution clarified in order to come closer to creating a safer community.

Air pollution in Dhaka is serious due to increasing population and associated motorization. In research done by the Department of Environment (DOE) and World Bank it was found that, although, existing air quality monitoring data is limited, it was clearly shown that the average ambient concentrations of suspended particulate matter (SPM) and airborne lead are higher than the Bangladeshi national ambient air quality standards and much higher than the World Health Organization (WHO) guidelines. In particular, the city's average SPM levels are about 2 times higher than the Bangladeshi standard of 200 $\mu g/m^3$ in residential areas and are more than 10 times higher than WHO's guidelines of 120 $\mu g/m^3$ (24 hours) in commercial areas. Lead levels are also high in comparison with other cities around the world. Although there is a lack of time-series data, the ambient air quality measurements available for 1990 and 1996 onward indicate that the air pollution is worsening. (Xie, 1998)

What is Lead?

Lead (Pb) is a heavy metal with no known physiological value in humans. Lead is an element that cannot be broken down into something else. Kidneys and organs cannot excrete lead, and it tends to remain in the body once ingested or inhaled. Almost any body tissue can absorb it, although 90 percent of it ends up in our bones. Unfortunately, not much information exists yet about the potential hazards of lead that comes from bone.

Lead has been in common use for thousands of years, known for almost as long to have serious health effects. In modern times it has been widely used in gasoline, batteries, alloys gunshot, paints, and building materials, especially plumbing, and is also a common contaminant from many industrial processes, including mining and smelting.

Lead is also found in food, from lead-containing pesticides, from contaminated soil, and sometimes from lead solders in cans. Lead soldering is being phased out in some countries, but is still common, though it is generally barred in containers for baby food. Lead solders cannot be seen, but lead-testing kits are available for consumer use. Lead is also a serious contaminant of wine, leaching from lead-foil caps and also from lead-soldering in pipes during processing; a study done in 1991 found such lead contamination widespread, often exceeding allowable levels in water, with imported wines--especially from Italy--having higher levels than US -produced wines. Other common sources of lead in food include imported glazed pottery and crystal glassware, from which lead oxide often leaches into wine.

Lead in old paints is also a great concern, from lead-laced dust from disintegrating paint flakes, which coat many of the surfaces and toys that children touch and mouth, and not only in poor areas, but also in many old houses in a wide range of areas, in most of which lead paint was routinely used. (Franck, 1992).

Because lead is an element, it does not decay. Thus, it does not lose its toxicity over time. In the human body, its half-life (length of time it takes an atom to decay) is measured not in weeks, months, or even years, but in decades. In the environment, its half-life is infinite. Once lead is disinterred from natural ores, it can be shifted from here to there, presenting a threat of greater or lesser immediacy at one location or another--but it does not stop being lead. For thousands of years, humans have dug up this metal and used it in ways that have contaminated the biosphere. But during most of our history as a species, humans have been exposed to only the small amounts of lead that entered the biosphere through weathering of the earth's crust and similar forces. The level of lead in human blood in preindustrial times has been estimated at around 0.016 millionths of a gram per deciliter (0.016 micro g/dl).

Today, however, average blood-lead levels in the United States are at least several hundred times higher. These are the legacy of decades of dispersive use of lead in paint, gasoline, plumbing pipes, and other products. Although blood-lead levels have declined

roughly threefold over the past two decades, in the wake of restrictions on the use of lead in gasoline, paint, and food-can solder, the current average level among children is estimated to be about 5 micro g/dl-300 times greater than in preindustrial humans.

Why Worry About Lead?

Recent decades have made clearer lead's devastating effects on health, especially affecting the kidneys, brain, central nervous system (CNS), heart, and circulatory system, by a variety of actions, such as inhibition of the hemoglobin required by oxygen-carrying red blood cells and deactivation of enzymes vital to the brain and nervous system.

The greatest concern of lead is its affect on children. 40-45% of ingested lead (Pb) is absorbed in children, but only 5-10% of ingested Pb is absorbed in adults. Pb is thought to deteriously affect the nervous, heatopoietic, endocrine, renal and reproductive systems. Because children absorb Pb more readily, the developing nervous system of children is more susceptible to the toxic effects of Pb. (Florini, 1993). Lead poisoning is, in the words of the U.S. Centers for Disease Control, the **"most common and societally devastating environmental disease of young children."** Enough exposure to lead affects brain development and overall intellectual functioning including IQ, memory, and attention span, and reduces the ability to learn. In one study (Port Pirie Cohort) it was concluded that low level exposure to Pb during early childhood is inversely associated with neuropsychological development through the first seven years of life. The US Centre for Disease Control issued urgent new warnings , alerting doctors that anything higher than 10 u/dl lead can be harmful to children (October, 1991). Studies conducted in the last 10 years suggest that ingesting the lead equivalent of three granules of sugar a day can slow development and may make children less intelligent.

So far unclear is what level of lead is low enough not to be dangerous. In the mid-1960s, government regulations regarded as acceptable a level of 69 micrograms of lead per deciliter (mg/dl) of blood; that level dropped by stages to 15 mg/dl by 1987, and is expected to fall even further.

Lead's potency is compounded by its persistence in the human body. Even minute exposures to lead accumulate in the body, producing effects that may endure long after the exposure ends. Once absorbed, lead is stored primarily in bone and, to a lesser degree, in the kidneys and the brain. Only a small portion circulates in the blood at one time.

The mobilization of lead from bone into the blood during pregnancy is of particular concern. Women who have borne children appear to have lower skeletal lead levels than those who have not, indicating that lead may have been transferred to the children during gestation and/or nursing. Mobilization of lead from bone can acutely intoxicate pregnant women who have high bone-lead stores. Moreover, the fetus is highly susceptible to the neurotoxic effects of lead, which moves freely across the placenta. In rare cases, babies can be born with clinical signs of lead poisoning. Inadequate calcium in the mother's diet during pregnancy and lactation may accelerate the mobilization of lead, providing another instance of the disproportionate impact of lead poisoning on the poor. (Florini, 1993)

Like other heavy metals, lead readily contaminates the environment, often being dissolved by acid rain or by water in the ground, as from industrial or mining sources, or being deposited from particles in the air. It enters the food chain and is stored in the body tissues of wildlife, with increasing concentration at every level in the chain. Animals high on the food chain--such as birds of prey and humans--are especially affected.

What is the Most Common Source of Lead that Poses Danger to Humans?

Pb is prevalent in society and a common use of Pb is in leaded fuels. In a study of blood lead levels (PbB) in shopkeepers and car traffic pollution in Liguria, Italy individuals who worked in streets determined as having exposure to high traffic amounts had statistically greater than average PbB values than those who worked in low traffic streets. A study of pregnant women in the urban slums in Lucknow, India showed that women who lived in inner city neighborhoods near heavy traffic had a PbB 2.2 ug/dl higher than those living in outer neighborhoods (the mean being 14.3 ug/dl). In monitoring blood levels in Hungary (started in the 1980s), data showed a strong relationship between PbB

of children and traffic. As a result of the reduction of the Pb content or petrol, the PbB of children decreased steeply in the early '90s. This decline was also illustrated in a chronological trend in PbB between 1976 and 1980 in a study in the USA. A 37% decrease in PbB was seen and the most likely explanation for this decrease is a reduction in the Pb content of petrol during this period. (Crowe, 1998).

Why Has Lead Been Used in Cars?

Lead is mixed with gasoline because it is an economical way of increasing octane ratings to match the increased compression ratios of the powerful engines that the public in the U.S. wanted. And a more efficient way to use petrol in most countries. Thomas Midgley from General Motors discovered in 1922 that adding less than 0.1% tetraethyllead to a gallon of gasoline, roughly one teaspoon per gallon, increases the octane number of the gasoline, by 10 to 15 points. The high octane ratings achieved with inexpensive leaded gasoline permitted the production of more powerful engines that would be free of knocking.

Knocking

The phenomenon of "knock" in spark-ignition internal combustion engines has been known to the practical engineer since at least 1882. In 1922 the addition of tetraethyl lead (TEL) to gasoline was first reported to be a very efficient method to suppress "knock" and it has been in widespread use since then. Rather more recently other lead alkyl compounds have also been used, particularly tertramethyl lead (TML) which is very popular in Europe. Subsequent research has not, up to now, produced satisfactory alternatives to the lead alkyls which have even comparable effects on the reduction of "knock".

There are however two problems associated with the use of leaded additives to gasoline:
-- firstly, all the added lead is eventually emitted into the atmosphere. As we have learned, this can have significant adverse health effects on children and adults. Furthermore, studies have shown that increased levels of body lead can and do cause

impairment of biological functions at levels below those associated with obvious signs and systems;

-- secondly, in order to produce increasingly fuel-efficient vehicles which will also meet, strict standards for exhaust emissions (carbon monoxide, hydrocarbons, nitrogen oxides), catalytic converters are a solution used or envisaged in a number of Member countries. Lead products react with the catalysts "poisoning" the active ingredient and thus rendering the exhaust converter ineffective.

Many OECD countries have recently made or are about to make major decisions on the levels of lead permissible in gasoline. The many health studies on lead do no always present scientifically irrefutable evidence and thus may not alone present a sufficient basis for government decision-making. The USA decided that the dual environmental problems of health effects and catalyst poisoning outweigh the added economic and energetic costs and has taken the initiative in opting for the use of unleaded gasoline in all new cars since 1975, reducing significantly the average lead content of all gasoline. (Untitled photocopy)

Catalytic Converters

By the middle of the 20th century increasing numbers of automobiles were spewing gases--unburned by hydrocarbons, carbon monoxide, sulfur dioxide, and various oxides of nitrogen--out of their tailpipes and into the air we breathe. For a chemical solution to a chemical problem, auto manufacturers turned to the catalytic converter. Since 1975, virtually all automobiles built or imported into the United States have been equipped with this device. A catalyst is any substance that speeds up a reaction but is not a reactant. The catalyst simply allows the reactants to come together to produce the very same products they would have generated in its absence, but much faster or under much milder conditions.

The automobile's catalytic converter consists of a large canister mounted between the engine's exhaust system and the tailpipe, containing finely divided platinum, palladium, and sometimes other substances as well. As the exhaust gases from the engine pass

through the converter, the finely divided particles of platinum and palladium catalyze the complete oxidation of unburned hydrocarbons and carbon monoxide into water and carbon dioxide, and thereby decrease the amounts of these atmospheric pollutants leaving the exhaust pipe. The catalysts themselves are sensitive to a form of deterioration called catalytic poisoning, in which another chemical coats their surfaces and renders them ineffective. Lead, in particular, can poison a platinum or a palladium catalyst. It's been estimated that using as little as two tanks of leaded gasoline can completely destroy the activate of a catalytic converter. For this reason the United States Congress made it illegal to use leaded gasoline in cars equipped with catalytic converters (unless, in an emergency, no unleaded gasoline is available).

As older cars not equipped with the converters have left active use, and as the demand for leaded gasoline has decreased, high-octane unleaded gasoline has steadily replaced leaded gasoline as the fuel of choice in autos. Today leaded gasoline is no longer available in most areas. Nationally, sales of leaded gasoline dropped from about 53% of all gasoline sold in 1980 to about 3.5% in 1991. (Snyder: The Extraordinary Chemistry of Ordinary Things).

Thus lead in gasoline is not only bad for the environment and health but also prevents the use of catalytic converters used to reduce other harmful pollutants.

Situation in Bangladesh

Janakhantha Daily Newspaper (28 April, 1998) stated that "Dhaka is the second most polluted city amongst the five most affected cities in the world. Jakarta, Indonesia is first in the list." According to the Executive Director of Bangladesh Center for Advanced Studies (BCAS) the concentration of lead in Dhaka city is 3 times higher than that of Khulna city. Statistical evidence shows that the concentration of lead in Dhaka city is 19 to 22 micrograms and in Khulna the concentration is 8 to 11 micrograms. Evidence was gathered by taking 10 blood samples each from individuals at the seminar for lead from Dhaka and Khulna. The source of air pollution is from cars, the maximum pollutants are two-stroke engines (baby taxis and tempos). 35,000 baby-taxis and 2000 auto-tempos are

polluting the environment most. The health of the drivers of these vehicles are severely at risk (300,000 drivers). Director of Kishon Automobiles informed the public that they will soon introduce a new type of smokeless tempo which will run by electricity. By next September of this year experimental tempos will run in Dhaka city.

A few tests have been conducted in Dhaka city for evidence of lead poisoning in humans. The maximum permissible limit (μg/dl) of lead in Bangladesh is 0.15. A study was carried out of blood lead levels (PbB) of 30 people in the Dhaka metropolitan area. The level of lead in each of the blood samples was 5 times higher than the maximum allowable limit. However, this study was considered inconclusive because of the small sample size used. It is "believed" that blood lead levels of metropolitan inhabitants are dangerously high. In another study of 93 adults it was found that the median PbB-level was 0.55, 45 times higher than the maximum permissible limit.

Copper and Langford (J.A. Cooper and J.C. Langford, "Trace Substances in Environmental Health", University of Missouri, p. 13, 1972) found that in the USA, the Pb content of nail is 10-100 times higher than that of blood. Khan et al. also found a similar proportion in Bangladesh adults: in nail 0.39-10.3 ppm; and in blood 0.2-1.0 ppm. The highest range in adult's nails being 55.0 ppm. In children's nails the Pb level is rather high: 3.6-66.6 ppm. Considering the lower limit of blood Pb content, this would indicate that children may have from 0.36-6.66 ppm of Pb in blood which would be equal to 0.36-6.66 μg/g.. These last figures will approximately be equal to 36μg-666μg/dl taking the density of blood as 1 unit. If the blood is 1.5 as heavy, then the lower limit is 24 μg/dl. The acceptable highest blood Pb level in children is 10 μg/dl. The figures will be more alarming if we calculate the children's blood Pb-level taking the mid-range values of the fingernail Pb-level.

The Independent, Dhaka 1 May, 1998 stated that a survey conducted by the Health Economics Unit of the Ministry of Health and Family Welfare has revealed that the level of lead concentration in the blood samples among the citizens of Dhaka has reached alarming proportions. Smoke, fumes and soot disgorged by the ever increasing numbers

of motor vehicles, particularly, those fitted with the two-stroke engines, are mainly responsible for this newly discovered hazard. Dhaka's dwellers are already exposed to health hazards of various kinds, and now there is this additional threat to their health.

According to health experts, the human body can stand only 10 micrograms of lead per decilitre of blood at its maximum. The 39 residents of Dhaka city who have been randomly selected from different social strata for the present study showed quite divergent proportions of lead content, ranging from 13 micrograms to the very high level of 132 micrograms of lead per decilitre in their blood samples. Most hard hit among those tested are the motor vehicle drivers with a level of 86 micrograms/decilitre, immediately followed by laborers who work out into the open with a level of 79.3 and policemen at 77 microgram/deciliter. The next group of vulnerable people are the commuters at a level of 55.8, especially those who frequent the various business centres of the metropolis. Those who work indoors are safer in comparison to the high risk groups mentioned. But if the level of air pollution continues to rise, they will also be similarly affected.

Sources of Lead in Dhaka City

Severe air pollution is threatening human health and economic growth in Dhaka. Using a set of dose-response functions reviewed and presented by Ostro (1994), Brandon (1997) who found that severe health problems could be avoided in Dhaka if the city's annual average pollutant levels were reduced to the Bangladeshi national standards. He estimated that taking this action would annually result in 3,580 few premature deaths, 10 million fewer restricted activity days, and 87 million few respiratory symptom days. The economic benefits associated with avoiding these health problems could range from a low estimate of $60 million to a high estimate of $270 million, equivalent to 1.7% to 7.5% of the city's gross product. Because these estimates hardly account for the costs associated with traffic jams, global warming, soiling of materials, and aesthetic degradation and because the Bangladeshi national standards are much less strict than the WHO recommended standards, the total cost of air pollution could be substantially larger.

Motor vehicles, especially two-stroke engine vehicles (TSEV), are responsible for the increase in emissions of both local pollutants and greenhouse gases (GHG), due to the rapid growth in the number and use of motor vehicles. Bangladesh national vehicle registration data shows that the total vehicle population in Dhaka has grown by 60% from 1990 to 1996. TSEVs have outgrown all other types of vehicles during the period; for example, the number of two-stroke engine three-wheelers has tripled (Bangladesh Bureau of Statistics, 1997). Table 1 displays vehicle population by type, utilization, and fuel economy. Three-wheelers (90% are two-stroke engine baby taxis) and two-wheelers (mainly mopeds and baby taxi with two-stroke engines) are dominant in the vehicles fleet in terms of both number and mileage.

Although baby-taxis and tempos are a major source of lead pollution, they are not the only source. All fuel in Dhaka is added with lead which means that any vehicle using fuel will be using leaded fuel and simultaneously emitting lead into the air. Thus, along with baby-taxis and tempos --cars, jeeps, microbuses, minibuses, and motorcycles are polluting the air with lead as significantly as two-stroke engines (baby-taxis, tempos). Since February 1997 Bangladesh has been importing lead free gasoline but mixing this with lead. Regular petrol is mixed with about .10 gms per litre and Octane (premium) with about .40 gms per litre (Ministry of Power, Energy and Mineral Resources). Baby taxis and tempos leach higher concentrations of pollution because two-stroke engines are not as efficient in burning fuel as four stroke engines. They also do not get serviced as regularly so harmful particulates compound within the engine.

Table 1. Vehicle population, utilization, and fuel economy in Dhaka, 1996

	Vehicle Population	Annual Utilization (km/yr)	Total Annual veh-km (millions)	Fuel Economy (km/l)
Cars (including taxis)	42,000	19,200	806.4	8.0
Jeep/Station wagon/Micro bus	12,000	19,200	230.4	8.0
Minibus	4,000	57,600	230.4	4.8
Diesel bus	5,000	64,000	320.0	2.4

Diesel truck	14,500	38,400	556.8	2.4
3-wheeler vehicle	31,000	40,000	1,240.0	20.0
2-wheeler vehicle	73,500	10,000	735.0	35.0

Sources: EEA, 1998; Dhaka Urban Transport Project Working papers

Initial estimates reveal that motor vehicles annually emit 3,700 tons of PM_{10}; 8,550 tons of nitrogen oxide (NOx); 50,700 tons of carbon monoxide (CO); 21,800 tons of hydrocarbons (HC); and 1.5 million tons of carbon dioxide (CO_2), the primary GHG (Table 2). Due to the rapid TSEV growth along with poor maintenance, excessive commercial use, fuel adulteration, and lubricant oil quality and quantity issues, TSEVs (especially three-wheeler baby taxis) contribute significantly to vehicular emissions in Dhaka. The shares of TSEVs in total vehicular emissions of PM_{10}, HC, CO, and CO_2 are 40%, 77%, 44%, and 13%, respectively.

Table 2. Baseline vehicular emissions inventory in Dhaka, 1996 Unit: 1,000 metric tons

	PM_{10}	HC	CO	NO_x	Lead	$C0_2$	CH_4
Light-duty gasoline vehicles	0.26	3.70	24.91	1.63	0.012	309	8.0
Minibus	0.21	0.12	0.30	0.58	0.003	115	8.0
Diesel bus	0.64	0.42	1.40	2.65	0	324	4.8
Diesel truck	1.11	0.74	1.91	3.61	0	563	2.4
3-wheeler vehicle	0.93	13.52	16.37	0.07	0.011	147	2.4
2-wheeler	0.55	3.31	5.81	0.02	0.011	50	20.0
Total	3.70	21.80	50.70	8.55	0.037	1507	35.0

Note: CO_2, methane (CH_4) and nitrous oxide (N_20) are greenhouse gases. The global warming potential (GWP) factors of CH4 and N_2O are 25 and 320 times that of CO_2, respectively (IPCC, 1996).

Using the dose-response functions presented by Ostro (1994) again and a simple area dispersion model, the World Bank team estimated that PM_{10}, emissions from TSEVs cause about 400 premature deaths, 343,000 restricted activity days, and 11 million respiratory symptoms each year. The estimated economic cost (based on foregone salary and medical costs) is about $18 million, which equivalent to $12,140 per ton of PM_{10} emitted and US $0.009 per kilometer driven. Two-stroke engine baby-taxis pollute intensively in terms of per vehicle and per kilometer driven. A typical baby taxi is driven 100 to 120 kilometers per day and 360 days per year. Dhaka's 30,000 strong baby taxis (less than 17% of total vehicle population) are responsible for 25% of total vehicular

PM_{10}, 62% of HC, and 32% of CO. The health-related economic cost is about $360 per vehicle per year. There is a need for action to control emissions from TSEVs, especially from two-stroke baby taxis if the assumptions made for this paper are verified.

Table 3. Motor vehicle emission factors-baseline uncontrolled. Unit g/km

	PM_{10}	HC	CO	NO	Lead	CO_2	CH_4	N_2O
Light-duty gasoline vehicles	0.25	3.57	24	1.6	**0.012**	298	0.04	0.17
Taxi	0.33	6	40	3.2	**0.012**	298	0.04	0.17
Minibus	0.90	0.5	1.3	2.5	**0.012**	498	0.09	0.097
Diesel bus	2	1.3	4.4	8.3	**0**	1011	0.05	0.025
Diesel truck	2	1.3	3.4	6.5	**0**	1011	0.05	0.025
2-stroke 3-wheeler	0.75	10.9	13.2	0.06	**0.009**	116	0.15	0.002
2-stroke-2-wheeler	0.75	4.5	7.9	0.025	**0.015**	68	0.15	0.002
4-stroke motorcycle	0.08	0.72	8.3	0.39	**0.0023**	36	0.13	0.002

Sources: selected from EEA, 1998; Iyer, 1997; TERI, 1997; Faiz, et al, 1996; and IPCC, 1995.
Note: There are no actual measurements of emission factors for Dhaka. The estimation of PM_{10} emission factors of TSEVs is based on emission measurements in other countries and takes into account the impact on emissions of such factors as the use of excess lube oil, fuel adulteration, and poor engine maintenance. These emission factors represent order-of-magnitude estimates only and require further verification. (Xie, 1998).

Motor vehicles are also responsible for the increasing emissions of Global Greenhouse Gases GHG's believed to be the cause of global warming. Bangladesh emitted 20 million tons of CO_2 in 1995 (IEA, 1997). The transport sector is an increasingly important GHG contributor, although it has less impact on global warming than it does on local public health. Nationwide, about 18% of CO_2 emissions come from road transportation. Unlike local pollution problems which are solely the responsibility of local activities, global warming is a result of human activities all over the world, especially in countries where the economy was industrialized a long time ago and the quantity of fossil energy consumption has historically been and still is very high. Nevertheless, seeking synergy in its pollution control programs for both local and global benefits is in the interest of Bangladesh.

Conclusion

It can be seen from this report and other research that lead pollution is a serious problem in Bangladesh. People are being affected and will continue to unless the situation improves. The good news is that there are several solutions and options that can be taken up to decrease lead pollution and other ambient pollutants. A few concerned individuals and organizations have already begun to look into the problem, including World Bank, the Department of Environment, WHO and ICDDRB. The problem lies in that these efforts are not conglomerated but rather, are spread out and in small quantities. Immediate and cohesive action on a large scale must be taken up to deal with the problem of lead pollution with follow up monitoring capabilities. Creating awareness is imperative. Solutions include emission control methods, demand management of motor vehicles via fuel taxes, economic incentives, regular vehicle servicing, traffic management, legislation and transport planning.

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