STRATEGIES TO PHASE OUT LEADED GASOLINE AND TWO STROKE ENGINES IN BANGLADESH: TECHNICAL, ECONOMIC, AND PUBLIC HEALTH CONSIDERATIONS.

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Abstract

Compared to the other megacities of the world, Dhaka has a small motorized vehicle fleet. It is estimated that less than five motorized vehicles are available per 1,000 people in Dhaka City. There are also no heavy industries capable of emitting large amount of pollution located near the urban area. Most of the urban industrial pollution activities occur at numerous small sources, such as, garment and textile industries, machine shops, auto-repair shops, brick fields, tanneries, etc. However, the measured ambient pollution level in Dhaka exceeds those of Los Angeles, London, Mexico City, etc. The previous studies have correlated high level of Dhaka City's ambient air pollution with the use of leaded gasoline, high sulfur diesel fuel, and two stroke engines. As the country develops and population grows, the vehicle fleet will increase too. In order to accommodate living space for an ever-increasing population, the cities will grow in size and the average daily commuting distance will rise significantly. All of these development activities will accompany a proportional increase in pollution and cause severe morbidity and mortality due to health effects.

It is, therefore, exigent upon the government policy makers and private stakeholders to embark upon a strategy to phase out leaded gasoline, high sulfur diesel fuel, two stroke engine auto-rickshaws and faulty vehicles. This paper discusses several technological options, cost and benefit, and implementation strategy for the phase out. Many of these strategies have already been proven successful in other parts of the world both in developed and under developed nations. Successful implementation of a phase out strategy not only requires regulation and enforcement, but also incentive policies, consensus among stakeholders, public information and education.

Human Health Effects of Lead

Human exposure to lead is a serious health problem. Lead is a hazardous heavy metal and a known neurotoxin. Scientifically, it is one of the best understood and widely studied environmental toxins. It severely damages many human organs, most notably the nervous system, the blood-forming system, the kidneys, the cardiovascular system, and the reproductive system.

Children's health is most vulnerable to lead because their nervous systems are not fully developed. Children of low-income families, most children of Bangladesh, are at special risk because nutritional deficiencies may exacerbate lead toxicity. Small children are particularly exposed to lead because they tend to eat dust and earth where ambient lead is deposited.

High lead content in youngster's blood is associated with reduced intelligence, hyperactivity and attention deficit, learning problems and behavioral abnormalities. Many studies in the western countries have found statistically significant relationships between the blood lead levels of children and their IQ gradients. After reviewing many studies, the US Centers for Disease Control (CDC, 1991) concluded that a 10 microgram/dl increase in blood lead level can be associated with a 2.5 gradient decrease in the IQ of children. In a study conducted in Hungary, children with 25 microgram/dl blood lead level showed a 10 point reduction in IQ compared to those children with less than 10 microgram/dl blood lead level.

It has been shown that even at a low level of exposure to lead, such as below 10 microgram/dl can cause serious and persistence damage to the nervous system. Although many national and international guidelines consider 10 microgram/dl as limit for concern, no threshold has been found below which adverse effects of lead cannot be detected.

Pre-natal or fetal exposure to lead causes adverse reproductive outcomes including decreased gestational age, reduced birth weight and skeletal growth, disturbed mental development, spontaneous abortion and premature birth, fetal death, and increased infant mortality.

Lead exposures in adults tend to raise blood pressure, hypertension, and other cardiovascular problems. Ostro (1994) has estimated that a 1 microgram/cubic meter increase in airborne ambient lead concentrations caused about 70 thousand hypertension in one million males aged 20 and 70 years, 340 non-fatal heart attacks, and about 350 deaths per one million males aged 40-59. Studies have also indicated effects of lead on male productivity.

Table 1 provides an overview of the major known health effects from lead exposure.

Population Group	Health Effects
Children	IQ loss Hearing loss Lower concentration Hyperactivity Other neurological effects
Adults	Hyper tension Neurological effects Non-fatal coronary heart disease Non-fatal stroke Mortality Possible Cancer Other cardiovascular disease Adverse reproductive effects
Fetal Exposure	Infant mortality Reduced birth weight Fetal deaths Decreased gestational age

Automobile Lead Emissions

More than 85% lead emissions from automobiles consists of highly toxic inorganic lead, which is easily absorbed into the body due to the small size of combustion derived lead particles. Ambient lead from vehicle exhaust may also travel a long distance and spread widely, although much lead is deposited on the soil in areas nearby heavily traveled roads, where it persists for a prolonged period.

A large body of data supports a strong relationship between the lead in petrol and blood lead levels. These data indicate that declines in the lead content of petrol can cause blood lead levels to decrease. Areas with high traffic experience higher ambient concentrations of lead. In Budapest, a study showed that children living in downtown areas had mean blood level of 24.8 microgram/dl, whereas those living in suburb had a mean level of only 7.6 microgram/dl.

Studies in the US have estimated that petrol contributed more than half of the blood lead burden in the 1970s when leaded petrol was in use. Studies also suggest that a decrease of 100 metric tons per day of lead used in petrol is associated with a decrease in mean blood concentration of 2.14 microgram/dl. In 1976, when leaded petrol was still used extensively in US, the average blood lead level of the population was 16 microgram/dl. As a result of gradual phase-out of lead in petrol, it dropped to 10 microgram/dl in 1980 and 3 microgram/dl in 1996.

Recent Bangladesh Government Initiatives

In February 1999, National Environmental Council of Bangladesh, chaired by the Forest and Environment Minister announced a decision to import unleaded petroleum from July 1, 1999. This is the first ever a government initiative to curb ambient lead level from Dhaka's air. Concurrently, the government also decided to impose high duties on the import of two stroke engines for auto-rickshaws and make a mandatory use of "catalytic converter" for buses, trucks, and other heavy duty vehicles. This imported fuel will have 0.2% lead, instead of 0.5% lead in current fuel. Thus, this is not completely a lead free fuel.

The first batch of lead free fuel, about 19,000 tons, was imported in July 1999 and became available in the market in late August. However, because there is no separate reservoir existed to store lead-free fuel either at the bulk terminals or at the individual pump-sites and gas stations, the lead free fuel was mixed with old stock of leaded fuel. Also, in absence of any enforcement mechanism, the individual pump station owners and consumers were reported to adulterate lead free fuel with the cheaper leaded fuel. Therefore, the purpose of importing cleaner fuel failed because the implementation was not planned and executed properly.

Why lead is added to the Petrol?

For many years, lead has been added to the petrol, as it is a relatively inexpensive source of boosting the petrol's octane number. The higher the octane number, the better is the anti-knock performance of the engine. At sufficiently high levels, lead addition can increase octane by as much as 10 to 15 numbers, but each increment of added lead provides a smaller octane boost than the previous increment. Lead also provides some engine lubrication benefit. Lead in

petrol prevents wear of engine valve seats in older vehicles with soft valve seats.

Technical Options for Lead Replacement

When lead is not added to petrol, the octane boost formerly provided by lead must be replaced. There are several choices available today in a modern petroleum refinery for replacing octane, which includes:

- Blend oxygenates such as MTBE (methyl tertiary butyl ether) into the petrol pool. MTBE has exceptionally high octane rating (115 RON) and other desirable blending properties. MTBE can be produced by combining methanol and iso-butene produced by the fluid catalytic cracking (FCC) unit of a refinery. If MTBE cannot be produced locally, a world trade of MTBE exists.

- Increase refinery production of high-octane blend stocks, such as FCC petrol, alkylate, isomerate, etc. by increasing utilization and, if necessary, expanding or revamping existing process units.

- Increase the octane of reformate, by increasing the utilization of reformer severity. The reformate generally has high aromatics and benzene content. Benzene is a known human carcinogen and exposure to benzene among other things increases the risk of leukemia. Therefore, increasing refinery severity to an extreme is not generally recommended.

Determining the options of choices calls for a detailed technical and economic analysis for the refinery. Worldwide experience and estimates indicate that annual investment expenditures and added operating cost associated with the removal of lead from gasoline are typically in the range of US$ 0.01-0.02 per liter of gasoline.

Cost effectiveness of lead phase out

Economic benefits of improved health

The Economic benefits of the lead phase out equal the avoided health costs resulting from vehicular lead emissions. For children, these costs primarily relate to reduced productive and earning powers over the lifetime. The economic benefits of avoided health impacts depend on country specific factors: the cost of labor and capital, labor productivity, life expectancy, cost of health care, etc. Concrete estimates for Bangladesh, therefore, are difficult to make without the country-specific data. Studies in western countries, however, may provide some indication of the magnitude of benefits. It was estimated, for example, that a one point IQ reduction could be associated with 0.9% reduction in lifetime earnings in the US. The annual benefits of reducing the population's mean blood levels by 1 microgram/dl were estimated at more than US $17 billion, that is, almost US$ 70 per person (Schwartz, 1994). As a result, the benefits of lead removal from gasoline were estimated to exceed its costs more than ten times in the US (US EPA, 1985).

Lower Maintenance Costs

The phasing out of lead results in lower maintenance costs from lead induced corrosion of exhaust system and lead buildup in engines. The cost of modifying the vehicle fleet to operate on unleaded petrol or the cost of lubricating additives may be compared to the savings in maintenance costs.

Existing Vehicle Fleet Considerations in Phasing out Lead

Bangladesh have a small motorized vehicle fleet. Most of the trips are made by non-motorized modes, such as by walking or using non-polluting and manual bicycles and rickshaws. Besides, most trips are made between a short distance. It is estimated that about 200,000 motorized vehicles exist in greater Dhaka metropolitan area today. The most polluting vehicle category includes about 50,000 two-stroke auto rickshaws, and a significant number of faulty buses and private cars. A large percentage of vehicle fleet is made up of older cars equipped with engines containing soft exhaust valve seats, which are believed to require leaded gasoline for its lubricant properties. The structure of such a vehicle fleet is often cited as a major obstacle to lead phase-out. However, research shows that amount of lead required for lubrication is much lower than the amount used in the current fuel of Bangladesh, and that 0.05 g/l lead is sufficient to provide the required effect. Secondly, lubrication can be provided by commercially available potassium and sodium-based lubricant additives. There is also evidence that many cars previously thought to need leaded gasoline can operate using unleaded gasoline. The cost of replacing lead as a lubricating additive has been estimated at approximately US$ 0.003 per liter of gasoline.

Vehicles with hard valve seats and without catalytic converters can use either leaded or unleaded petrol. For these vehicles there is no technical constraints for using unleaded petrol. Bangladesh do not domestically manufacture cars, but imports them mainly from other Asian countries. Since car manufacturers around the world predominately produce vehicles with hard valves these days, and Bangladesh imports cars no older than five years, majority of private cars in Bangladesh should be able to use unleaded fuel. However, experiences from other countries show that owners of such cars may be reluctant to shift to unleaded petrol. The reluctance stems from a skepticism as to the applicability of unleaded petrol. Furthermore, if tax differentiation schemes are not applied, leaded petrol will be cheaper than unleaded petrol.

Vehicles equipped with catalytic converters must use unleaded petrol for the catalytic converter to be operative. Vehicles with two stroke engines can use either leaded or unleaded petrol. Several manufacturers produce engines with low compression ratios and therefore low octane requirements down to octane number 80. Low octane fuel is easier to produce, and may not need any added lead.

The Global Schedule for Lead Phase Out

Asia/Pacific Region:

India began marketing unleaded gasoline in 40 cities by 1998. Cars bought in the four major

cities since April 1996 must be fitted with the catalytic converters. By 2002, India expects a complete phase out of leaded gasoline.

Philippines began offering unleaded gasoline in metro Manila in 1994. New Zealand made it illegal to sell leaded gasoline as of September 30, 1996.

China banned leaded gasoline in Beijing as of January 1, 1998. The national date for the elimination of leaded gasoline is January 1, 2000.

Indonesia declared that it would eliminate lead in gasoline by 2000. Taiwan announced in 1994 that it would eliminate the use of leaded gasoline by the year 2000.

The Americas

As of January 1, 1996, it became unlawful to sell leaded gasoline for use in motor vehicles in the United States of America. Mexico, Ecuador, Barbados, and Trinidad/Tobago plan to phase out leaded gasoline by the year 2001. Starting in 1997 Argentina, Belize, Costa Rica, El Salvador, Honduras, and Nicaragua only use unleaded gasoline.

Europe

The European Union drafted a proposed directive for a complete ban on leaded fuel by 2000. Slovakia eliminated leaded gasoline in 1995 and Hungary required all new cars since 1994 to have catalytic converters and use unleaded gasoline.

Middle East and Africa

Egypt phased out leaded gasoline by mid-1997. Israel banned the sale of 91-octane leaded gasoline, which took effect January 1, 1997 and announced a complete phase out by 2004.

South Africa introduced unleaded gasoline in February of 1996 with economic incentives to encourage consumption. Zimbabwe introduced unleaded gasoline as of October 1996.

Elements of an Effective Lead Phase out Program

The core aspects that need to be addressed include: regulations, enforcement and control, incentive policies, international cooperation and support, consensus among stake holders, public information and education.

Regulations

In countries like Bangladesh which imports its gasoline or crude oil have no serious technical constraints to accelerate the phase out of lead. Worldwide experiences show that a strong political commitment is necessary to introduce and enforce regulations aimed at mitigating human exposures to lead. The first step should be the reduction of high maximum

permitted concentrations to lower levels such as 0.15g/l or less. Further steps should include a deadline for the total elimination of lead. Regulations of the maximum allowed lead concentration may also be combined with other gasoline quality specifications such as octane rating, volatility, the content of aromatics, benzene and oxygenates. International reference specifications may provide guidelines

Enforcement and Control

Regulations are only effective if proper enforcement is available to ensure compliance. When the maximum allowed lead content in gasoline is regulated, it should be ensured that (1) refineries and importers comply with specifications; and (2) distributors and retailers do not mis-manage the various brands. While control and enforcement of gasoline specifications may be relatively simple at the production and wholesale level, it may require a more significant administrative effort at the distribution and retail levels. The use of colored dyes in the various gasoline brands and differed nozzle sizes at the pump may help the separation of leaded and unleaded gasoline in Bangladesh, administrative corruption, lack of appropriate resource, procedure, and technology may be an obstacle to efficient enforcement and control.

Incentive Policies

Incentive policies can play a major role during the transition period of lead phase-out by influencing gasoline demand and supply. Differentiated tax mechanisms can change the pump prices of leaded and unleaded gasoline in manner that, at comparable octane numbers, the price of unleaded gasoline becomes less than leaded gasoline. Many countries have used the differentiated tax mechanism to successfully phase out lead in petrol. In order to minimize mis-management of the various gasoline brands and abuse of the tax system by retailers, it is best to impose tax differentiation at the production level built into the refinery cost. Also, additional tax could be levied on the import or sales of lead additives, thereby, increasing the cost of producing leaded gasoline. In the longer term, the availability and lower prices of unleaded gasoline facilitate the wider use of cars equipped with catalytic converters.

Market based incentive mechanisms, for example, a lead credit trading system could also be considered. A system of lead credit trading can be used to provide flexibility to refiners in meeting lead content specifications. Under this system, refiners that produce gasoline with less lead than the standard obtain credits which in turn can be sold to refineries whose costs in meeting the standard are unacceptable. Lead credit system particularly works for countries with a large gasoline market and multiple refineries. The U.S. employed this type of system in the latter stages of its lead phase out program.

International Co-operation and Support:

External technical assistance is crucial to achieving a phase out of lead in petrol. External technical assistance can prove highly beneficial in the framing of strategies, action plans and possibly also in relation to refinery modernization plans. External technical assistance can also facilitate experience sharing and provide the necessary supply of human resources to accelerate the process. Training and institution building to improve the ability to enforce petrol

standards could also prove an important component of the technical assistance. Thus, bilateral and multilateral western assistance has important roles to play in the process of phasing out lead in Bangladesh.

Stake Holders Consensus Building

A successful lead phase out policy must be implemented with the full support and participation of several government agencies, industries, public organizations, and civic groups. The cooperation of government agencies responsible for environment protection, public health, and industry is necessary to set targets and determine a feasible schedule of lead phase out program.
In order to introduce tax incentives, support from the financial and tax authorities is important. Additionally, coordination with the government agencies responsible for transport sector provides information about the characteristics of the car fleet and fuel consumption. Cooperation among gasoline producers, distributors, and retailers is essential to ensure the supply and distribution of unleaded gasoline.

Public Information and Education:

A lead phase out program would be doomed for failure if consumers and the public do not understand and support the objectives of the program. Many people lack the knowledge about the severity of health hazards resulting from lead, or believe that they could not do much to mitigate the problem. Additionally, the lack of information, and misconceptions about using unleaded gasoline in older vehicles represents one of the largest obstacles to changing consumer behavior. Measures to facilitate lead phase-out process, therefore, should include general public education, and targeted dissemination of information and training.

Using the mass media and education campaign directed at the general public could better inform people about the health hazards of lead, educate motorists about the feasibility of using unleaded gasoline. Oil companies, car dealers, retailers, and public health agencies can publish and distribute information booklets with detailed information about lead health hazard, recommended fueling about different car models and model years, etc.

A Real life Example: How Costa Rica phased out lead?

A series of events led to the elimination of lead from gasoline in Costa Rica:

- Promulgation of Decree 19,088-S-MEIC-MIRENEM, which established a seven-year period to eliminate lead from gasoline (1989).
- Introduction of 95-Octane super gasoline, which is imported (1990).
- Undertaking of technical studies to evaluate alternative options for producing for producing unleaded gasoline with 88 Octane (1991-92).
- Promulgation of the Transit Law, which establishes requirements for motor vehicle registration and emission standards (1993).
- Opinion survey of regular gasoline consumers to gather their views about the introduction of unleaded gasoline to the market and to devise a public awareness campaign strategy (1994).

- Introduction of an environmentally friendly super gasoline (1994). This gasoline is produced by blending imported high-octane unleaded gasoline with 10% by volume MTBE content (also imported).
- A massive campaign on the benefits of environmentally friendly super gasoline through television announcements and distribution of pamphlets (1994).
- Establishment of an inter-institutional commission for all entities involved in the elimination of lead from gasoline, including vehicle importers, the agency in charge of regulating prices, the Costa Rican refinery (RECOPE), fuel consumers, and ministries of the environment, energy, public works, and transportation (1994).
- Evaluation of the impacts of lead elimination from regular gasoline (1995).
- Use of unleaded gasoline in RECOPE's entire fleet to prove to consumers that unleaded gasoline has no adverse impacts on engines (1995).
- Reduction of the price difference between regular and unleaded gasoline to 5% (1995).
- Promulgation of decree 24,637-MIRENEM-S, which prohibited the use of leaded gasoline in public institution vehicles (1995).
- Introduction of new unleaded gasoline called "bio-plus" (April 1996). This was done without any public announcement to allow time to clean the storage and distribution network of any residual lead. Bio-plus is prepared by blending naphtha produced by RECOPE and imported high-octane naphtha.
- Announcement of the introduction of bio-plus to the market and associated media campaigns through television and press (May 1996).

Source: Costa Rica Ministry of the Environment and Energy (1996)

Replacement of Two Stroke Engines

The two stroke engines utilized in auto-rickshaws and motor cycles contribute a disproportionately large percentage of the carbon monoxide, particulate matters, and toxic organic compounds. This is due to the fact that these engines have extremely inefficient combustion characteristics. Approximately 30% of the fuel used are not burned at all and are emitted as row gasoline into the atmosphere. Another third of the fuel is only partially combusted and is emitted as CO. Significant particulate matter emissions result from large amount of unburned motor oil, which is added to the gasoline to provide lubrication for the cylinder.

Equivalent motor cycles and auto-rickshaws that employ far more efficient four stroke engines incorporating timed fuel injection and crankcase lubrication are readily available and could meet the same transportation needs. On a per kilometer traveled basis, moderately controlled four stroke motor cycles have about six times less organic gas and eight times less particulate matter emissions than their two stroke counter parts. In order to replace two stroke auto rickshaws, Japanese light duty vehicles equipped with both four stroke engines and catalytic converter can be considered based on capacity, and road geometry requirement in Bangladesh.

In the long run, natural gas vehicles might find a niche market in Bangladesh considering the country's prospect for future production of abundant natural gas. Even with only modest pollution control in place, natural gas has much lower particulate matter and SO2 emissions than

any fuel oil. Concurrent with the delivery of the domestic natural gas, the urban bus fleet and other heavy duty vehicle fleets can be converted to natural gas fueled engines. The establishment of convenient natural gas fueling stations through out the urban area will facilitate faster introduction of the natural gas vehicle fleet.

Also, the battery powered electric bicycles capable of 25-35 miles per hour speed are available and used in many Asian countries including India, China, Taiwan, Vietnam, etc. At a comparable cost to the mechanical bicycles, these battery-operated bikes can serve as alternative means of transportation for many city dwellers plying through narrow and poorly maintained road networks.

Reducing Sulfur Content in Diesel

The sulfur in diesel fuel is a significant contributor of emissions of sulfur oxides. These oxides consist of about 90% sulfur dioxide (SO2) and up to 10% particulate sulfates (SO4). The SO2 is converted to particle sulfate in the atmosphere, which further worsens PM problems. Under favorable conditions, this conversion can involve a majority of the SO2.

The current sulfur content of diesel in Bangladesh is about 0.5-1.0% sulfur by weight, compared to less than 0.05% in Europe and US. The cost of reducing sulfur content of gasoline to 0.05% is about 1 cents per liter and technology to remove sulfur (desulfurization) is very mature and effective.

At the time of rebuild, authorities can consider replacing diesel engines with gasoline engines for light to medium duty vehicles for passenger transport in metro Dhaka (Jeeps and Utility vehicles). Gasoline vehicles inherently have much lower PM emissions and will create much less air quality problem than that produced from the existing diesel powered fleet.

Conclusion

The phaseout of lead from gasoline is a complex issue which requires understanding the health impacts of lead, technical considerations and solutions, and enabling policies and requirements for implementation.

Lead is a cumulative neurotoxin, which severely impairs the brain development of children. Investigations have confirmed that statistically significant correlation exists between the exposure of people to lead and reductions in their intellectual performance. Atmospheric lead exposure to adults has been connected to elevated blood pressure causing hypertension, heart attacks, and premature death. Vehicular traffic is the largest source of lead exposure in urban areas, often accounting to more than 90% of all atmospheric lead emissions. Although the value of the economic benefits of avoiding the health damage caused by the exposure to lead is country specific, the magnitude of benefits estimated in the United States suggests that phasing out lead from gasoline is likely to produce substantial benefits in all countries.

Worldwide experiences have proven the economic and technical feasibility of phasing out leaded petrol. The cost of phasing out leaded gasoline, including investment costs and the

incremental costs, has been estimated in the range of US$0.01-0.02 per liter of gasoline. Therefore, the removal of lead from gasoline is a highly cost effective measure. In the United States for example, the benefits of phasing out lead were estimated to outweigh the costs more than ten times.

Implementing lead phaseout program requires a broad consensus among the main stakeholders, and the understanding and acceptance of the program by the public. The phaseout should be supported by direct regulations, such as fuel specifications limiting and ultimately prohibiting the use of lead. The Government can influence the composition of gasoline demand by creating price incentives in favor of unleaded gasoline. In the long run, the increasing use of new cars equipped with catalytic converters is likely to result in the phase out of leaded gasoline, but this will be a very slow process considering the slow fleet turnover rate in Bangladesh. It is highly recommended that a successful lead phaseout program in Bangladesh includes the following six critical elements:

- Announce a clear lead phaseout schedule and deadlines
- Provide fiscal incentives to create a price structure favoring unleaded gasoline
- Provide free market conditions or price incentives to ensure implementation of investments
- Promulgate regulations to allow flexibility in implementations and enforce these regulations
- Build consensus among affected stake holders; and
- Provide public information, education, and training.

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