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DIESEL VEHICLES EMISSIONS CONTROL IN BANGLADESH

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ABSTRACT

In Bangladesh diesel vehicles maintain a uniform share of about 19~20% of total vehicle population. Most of these vehicles are commercial, old and poorly maintained. A recent study identifies buses, mini-buses, trucks, and light and medium duty diesel vehicles as the gross polluters in Bangladesh. The air quality in Dhaka reflects very high particulate matters (PM 2.5) concentration in its ambient air, for which diesel vehicles are primarily responsible. There is an urgent need of an emission control strategy and an enforcement program for Bangladesh in general and the capital in particular to mitigate the adverse effects caused by diesel vehicle emissions. Some strategies include revision of the emission standard, strict inspection and maintenance program, alternative fuel, electronic fuel injection, turbochargers, and catalytic converters for diesel vehicles. Emission control strategy is guided by socio-economic condition, effective but cheaper technology, presence of enforcement infrastructure and sincere desire of government machineries and general population. If these strategies are sincerely implemented, a cleaner and healthier environment can be presented to the future generations.

Keywords: Diesel Vehicles' Emissions, Diesel Vehicles' Standard, Emission Control Strategy

INTRODUCTION

The diesel engine, which uses compression ignition and injects high cetane fuel directly into the combustion chamber has become the dominant type in automobile industry. Diesel vehicles are cheaper to run because of its fuel economy, less maintenance cost and better performance in comparison to the petrol vehicles. In a recent initiative some motor industries have been conducting an enthusiastic campaign to promote diesel vehicles as environmental friendly vehicles. Although diesel vehicles emit less carbon monoxide and hydrocarbons than those of petrol vehicles, they emit more nitrogen oxides and particulate matters. More so diesel vehicles emit 'black smoke', the visible nuisance in urban areas. Total emission from diesel engines is more as most of these vehicles are commercial and they have a very high daily utilization rate.

In Bangladesh diesel vehicles maintain a uniform share of about 19~20% against 80% petrol vehicles of the total vehicle population (See Figure1). Here diesel vehicles are mostly Buses, Mini-Buses, Trucks, and Light and Medium Duty Vehicles (Jeeps, pick up vans, human haulers, light trucks, microbuses etc).

A recent study by the Department of Environment, Bangladesh shows that apart from 3 wheeled 2 stroke taxies, Buses, Mini-buses, trucks, and light and medium duty vehicles are the gross polluters in Bangladesh.

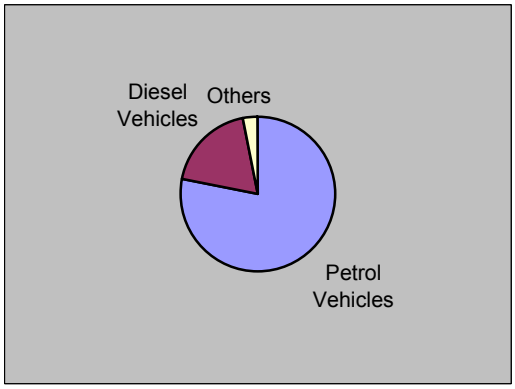

Figure1: Comparison of Petrol and Diesel Vehicles in Bangladesh

This paper in its limited scope tries to project the diesel vehicles growth in Bangladesh, their emission characteristics, and where they stand comparing with the 'Vehicle Emission Standard' of Bangladesh. The paper will also explain briefly the diesel vehicle's emission control technologies and finally recommends some strategies to mitigate their pollution emissions.

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DIESEL VEHICLES

Almost all heavy-duty trucks and buses, light and medium duty vehicles and some cars are diesel engines. Diesel engines are preferred for high efficiency, which is caused by high compression ratio (16~19), lean mixture of fuel (0.2~0.8 F/A equivalence ratio), and low pumping loss due to throttling. In diesel or compression ignition (CI) engines, air alone is taken into the cylinders and compressed to raise the temperature of compressed air to usually 538^0C. At this point the diesel fuel – a light oil of high cetane number is injected at a high pressure in the form of spray into the cylinders. The compressed hot air ignites the fuel, combustion takes place and power stroke follows. Generally there are two types of diesel engines:

Indirect Injected Engine (IDI)

In this type the fuel is injected into a small pre-chamber, where it ignites and combustion begins. Then the burning mixture flows into the main combustion chamber and completes the combustion. This type is applied to light vehicles and cars. This type of engine gives less emissions but fuel consumption is more in comparison to the direct injected engines.

Direct Injected Engine (DI)

Here there is no pre-chamber and diesel fuel is directly injected into the main combustion chamber. All heavy- duty vehicles are DI engines. DI engines are replacing the IDI engines because of their better fuel economy. As diesel is directly injected into the combustion chamber they have more emissions than that of indirect injected engines. In Bangladesh majority of the diesel vehicles are direct injected.

DIESEL VEHICLES' GROWTH IN BANGLADESH

Diesel vehicles constitute about 20~22% of total vehicle population in Bangladesh in comparison to about 80% of petrol vehicles. Out of these 80% petrol vehicles, about 40% are motorcycles. Surprisingly in contrast to other developed and developing countries diesel vehicles maintained almost a constant rate of growth during the last seven years in Bangladesh (See Figure2). In 1995, there were 57082 diesel buses and trucks i.e. 22% of total vehicle population, whereas in 2001 they are 75759 i.e. only 20% of the total vehicle population. During these seven years their numbers have grown by about 38%. On the contrary, the rate of new vehicle registration from 1995 to 2001 is negative (-1%). In 1995 about 7537 new diesel vehicles were registered, whereas in 2001 it is only 7455. Therefore, majority of the diesel vehicles in Bangladesh are old, very old.

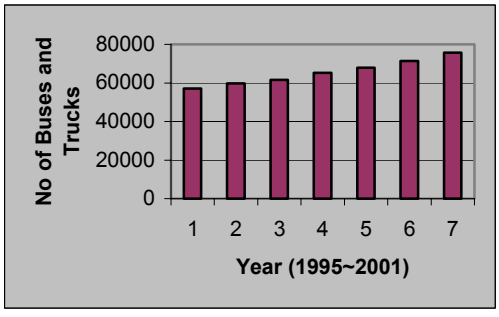

Figure 2: Growth of Buses and Trucks

EMISSIONS FROM DIESEL VEHICLES

Vehicle emissions result from either combustion (complete or incomplete) or evaporation. Emissions from diesel engines vary with driving modes, engine speeds, load, fuel and oil quality, maintenance practices, and the type and condition of the engine. Generally direct injected diesel vehicles emit more pollution than indirect injected engines and heavy-duty vehicles emit more than light-duty vehicles. The major pollutants from the diesel vehicles are carbon monoxides (CO), hydrocarbons (HC), nitrogen oxides (NO_x), particulate matters (PM) and black smoke. Most of these pollutants come from the exhaust. As diesel vehicles operate at high air-fuel ratios, they emit less HC and CO. Experiments have shown that light duty diesel vehicles, compared with similar petrol engines emit about 90% less HC and CO, and about 50~70% less NO_x. On the other hand, heavy-duty diesel vehicles emit 50~100% more NO_x but 90~95% less HC and 98% less CO than that of petrol vehicles. PM emissions from diesel vehicles is 6~10 times more than that of petrol engines. Diesel smoke is a visible public nuisance, which at a higher rate can be related to diesel PM emissions. Sulfur-di-oxide (SO_2) emissions from diesel vehicles may not significantly deteriorate air quality beyond acceptable levels. Therefore, NO_x and PM are the two most troublesome emissions from diesel engines.

HEALTH HAZARDS FROM DIESEL VEHICLES POLLUTION EMISSIONS

Vehicular air pollutants have a number of adverse effects on human health. The routes of exposure to the pollutants originating from vehicle exhausts are: inhalation, contaminated foods and water, and absorption through the skin. An inhalation exposure directly affects human's respiration, nervous, and cardiovascular systems resulting in impaired pulmonary functions, sickness and even death. Although diesel vehicles emit CO, HC, and SO_x, the affects of NO_x and PM on human health are described in the following paragraphs considering their high level emissions.

Nitrogen Oxides

So far it has not been proved that NO is health hazard. But NO_2 has some serious affects on human health. It is carcinogenic and it irritates alveoli leading to emphysema (abnormal inflation of the body). Exposures to NO_2 are linked with increased susceptibility to respiratory infections, increased airway resistance in asthmatics and decreased pulmonary function. Its exposure is also associated with a wide range of illness of children like cough, runny nose, and sore throat.

Particulate Matters

Diesel vehicle emission contains particulate matters largely less than 2.5-micron (10^{-6}m) size. These particulates consist mostly of three components: soot formed during combustion, heavy hydrocarbons condensed or absorbed on the soot, and sulfates. PM 2.5 can evade the human bodies' respiratory defense system and reach the lung tissue. There they can remain for years and be absorbed in the blood stream. It is associated with

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increased mortality and reduced lung function resulting from coughing and respiratory diseases, such as pneumonia, asthma, and bronchitis. Based on a review of research the International Agency for Research on Cancer (IARC) concluded that diesel PM emissions had possible carcinogenic effects on human.

STANDARD OF DIESEL VEHICLES IN BANGLADESH

Unfortunately the standard of diesel vehicles in Bangladesh is not at all satisfactory. The Department of Environment, Bangladesh in a recent study identified the trucks, buses, and light and medium duty vehicles as the gross polluters of environment. During June 2002 and February 2003 they have collected smoke emissions data from 503 in service diesel vehicles including 141 Double Decker Buses, 169 Buses and Mini-Buses, 105 Trucks, and 88 Light and Medium Duty Vehicles. The result of smoke emissions of these vehicles measured with a Hartridge Smoke Meter at free acceleration is given in the following table:

Table 1: Percentage of diesel vehicles below different free acceleration smoke levels:

Free acceleration smoke, % opacity	All Buses	Trucks	Light & Medium duty vehicles
60	*52*	*19*	*19*
65	*56*	*23*	*20*
70	64	26	23
75	69	28	26
80	76	32	27
90	85	50	36

Note: 65 HSU is the maximum limit for diesel vehicles in current Vehicle Emission Standards

The status of diesel vehicles presented above is very much disappointing. Considering the present diesel vehicle emission standard of 65 HSU, about 57% of all diesel vehicles are gross polluters. The case is worst for trucks, and light and medium duty vehicles. Only 50% trucks and 36% light and medium duty vehicles come within 90 HSU!!! Therefore, a large percentage of diesel vehicles are significantly polluting the environment of Dhaka city. The poor emission standard of these vehicles reflects their old age, poor maintenance, over loading, miss-fuelling or tampering with the engine setting, lack of public awareness and above all the absence of any emission control system.

EMISSION CONTROL TECHNOLOGY

Technically the control of vehicle emissions generally takes combination of the four forms depending upon the process, fuel types, and availability of equipment and the maintenance practices:

a. Inspection and maintenance of the diesel fleet
b. New Technology Diesel Vehicles
c. Ultra low sulfur diesel or environment friendly alternative fuels such as Compressed Natural Gas (CNG)
d. Exhaust gas treatment

Inspection and Maintenance (I&M)

Regular and periodic inspection and maintenance of vehicles ensures their proper functioning and thus helps to reduce emissions. It also ensures that benefits of the new fleet are not lost due to poor maintenance. A study carried out by Professor Don Stedman from the University of Denver suggests that 80% of vehicular pollution comes from 20% of the vehicles, which are predominantly poorly maintained. A relatively new vehicle fitted with catalytic converter can emit higher emission than a properly maintained old vehicle. Society for Urban Environmental Protection (SUEP) recently carried out the smoke measurements of some new TATA City Buses and TATA and TOYOTA Human Haulers. The majority of these vehicles were found to be grossly polluting. The primary reasons for higher pollution as revealed are the lack of maintenance practices in Bangladesh and their high daily utilization rate. Traditionally the owners and drivers do not give adequate importance to preventive maintenance because of the costs involved and lack of enforcement system. They completely forget that effective maintenance and repair of vehicles not only reduces pollution emissions but also improves fuel economy and gives vehicles a longer life.

A comprehensive study on 615 diesel vehicles undertaken by the National Environmental Protection Council in Australia (NEPC, 2001) found that significant reductions in PM emissions could be achieved through minor repair. The European Union and the California Air Resource Board (CARB) took similar I&M Program in 1990 and 1991 respectively and achieved about 36% and 54% reduction in PM emissions. (Figure3)

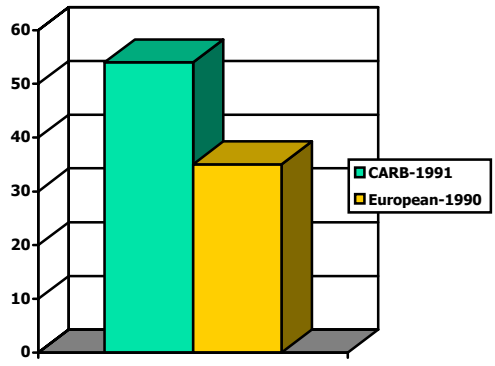

Figure3: % of PM Reductions through I&M

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These repairs were related to fuel injectors, fuel filters and fuel pump settings. Repairs to inlet manifolds, adjustments of tappets and other non-fuel components also provided significant emissions reduction. Therefore, with regular maintenance of diesel vehicles, emissions can be significantly reduced. A comprehensive I&M program and its proper compliance are essential to generate these maintenance practices.

New Technology Diesel Vehicles

Advanced technologies in diesel engines such as electronic controls, high pressure fuel injection, variable injection timing, improved combustion chamber configuration and turbo charging have made the diesel engines cleaner, quieter and more powerful than the past. All these systems make it possible to deliver precise amounts of high-pressure fuel from the fuel pump to the injectors and from the injectors to the cylinders. Then with a precise air stream from air filters and the turbo charger, complete combustion occurs. Combining all these will certainly reduce diesel emissions and improve performance. Experiments have shown that European engines with above technology can reduce PM emissions by more than 80% and NO_x emissions by 50 to 70% compared to uncontrolled levels. At the same time engine power output per unit of weight or displacement has increased by more than 30%. Fuel efficiency has also improved by about 20% compared to the engines of two decades ago. The updated vehicle emission standards can ensure the introduction of above technologies through strict limit of the criterion pollutant.

Ultra Low Sulfur Diesel (ULSD) or Environment Friendly Alternative Fuels like Compressed Natural Gas (CNG)

The ultra low sulfur diesel contains very low sulfur (50 ppm sulfur or even less). At present some countries like USA and Sweden use this low sulfur diesel in their diesel fleet. By 2005 almost all European countries and Japan will start using this ultra low sulfur diesel. This low sulfur diesel is super refined for clean and complete combustion. It gives better fuel economy, longer engine life, better performance, significantly reduces PM emissions and also enables the use of emission treatment systems like Diesel Particulate Filters (DPF). In UK it has been observed that with a reduction of sulfur content from 0.2% to 0.05%, there was 17% reduction in PM emissions.

The scenario in Bangladesh is different. Here, the commercial diesel has approximately 7000 ppm sulfur. To reduce it to low sulfur diesel would involve millions of dollars. Experts estimated a price differential of about $ 1~2 per barrel (1 barrel= 159 liter) for 500 and 1000 ppm sulfur. In Dhaka particulate emissions are mostly carbonaceous, which can be attributed to the poor maintenance of vehicles. Therefore, reducing sulfur in diesel without achieving significant improvements in vehicle maintenance practices would not have any significant effect on air quality. Policy makers will have to make a balance on this issue considering above factors.

One approach could be to have a road map of reducing the sulfur content to 500 ppm in next few years along with improvements in vehicle maintenances and then thinking of reducing further to 50 ppm. Because, 50 ppm sulfur diesel not only allows the retrofitting of emission control system like DPF and use of future advanced diesel engines but also significantly reduces PM emissions. It also makes sense as majority of the quantity of diesel in Bangladesh is imported.

On the other hand we have the alternatives – the readily available environment friendly compressed natural gas (CNG). As our diesel has high sulfur and as there are no infrastructures available within a short time, it is highly recommended that the diesel buses and minibuses in Dhaka City should be transformed into CNG vehicles. The CNG is less costly, has no problem of adulteration and more importantly produces much less emissions.

Exhaust Gas Treatment

With the introduction of ultra low sulfur diesel, a number of exhaust control systems such as diesel particulate filters, oxidation catalysts, particulate traps and diesel catalytic converters can be incorporated in diesel engine exhaust systems. These are some filter elements, which collect PM and convert Nitrogen Oxides (NO_x) into harmless Nitrogen. Experiments have proved that emission control system such as diesel particulate filters can control PM and NO_x emissions by about 80~90% and 25~50% respectively. Care must be taken so that these filters are not clogged or become inactive. Therefore a regeneration system has to be incorporated with these after-treatment systems, and again, rigorous engine maintenance is required. Considering the present quality of diesel (0.7% sulfur) in Bangladesh, using diesel particulate filters or oxidation catalysts is a distant reality. But the diesel catalytic Converter and particulate traps will be appropriate and effective. One should also think of the use of vertical exhaust, which reduces the local concentration of pollutants.

DIESEL VEHICLE EMISSION CONTROL STRATEGIES FOR BANGLADESH

The growth of transport sector inevitably exposes a large percentage of urban population to automobile pollution emission. Diesel vehicles with their NO_x and PM emissions pose a serious threat to the inhabitants of Dhaka city. Hence, there is an urgent need of an emission control strategy and an enforcement program for Bangladesh in general and the capital in particular to mitigate the adverse effects caused by vehicle emissions. The common approach to address this problem in many developed and developing countries includes: establish emission standards, installing emission control equipment, effective vehicle inspection and maintenance program, ensuring cleaner fuel, efficient traffic management, and introducing road tax system. But before introducing any such approach, careful and deliberate considerations have to be given on cost-benefit analysis for engine modifications or retrofitting control measures, and public awareness and their acceptance to the pollution control program. Basing on the emission control technologies, keeping in mind

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the above issues and considering the effectiveness of the control measures, some strategies for abatement of diesel vehicle pollution compatible to Bangladesh are suggested below:

a. Revision of the present diesel vehicle smoke limit and setting it to 70/80 HSU for in-use vehicles to ensure that majority of the diesel vehicles would be fit. This would reduce the evasion trend and prevent corruption on a wide scale. More importantly, it will help in getting the public support for the program.
b. There should be a stringent limit (Euro II) for imported diesel vehicles. This standard will ensure that substandard diesel vehicles are not dumped into the communication network of the country.
c. There should also be a comprehensive inspection and maintenance (I&M) program to identify grossly polluting vehicles. If these vehicles can be identified then repair and maintenance of these vehicles will significantly reduce the pollution emission. Because study has proved that only 20% of total vehicles contribute 80% of pollution emission.
d. Strict enforcement of the vehicle emission standards has to be implemented. Annual inspection of all diesel vehicles coupled with periodical inspection of commercial vehicles to be carried out for strict compliance.
e. As overloading increases vehicle emissions, efforts should be made to identify those vehicles and impose punitive measures on them.
f. Encouraging alternative fuel i.e. Compressed Natural Gas (CNG) for the commercial and public transport because CNG offers the most benefits in terms of combustion and pollution emission and diesel engine can run on it although with some complex alterations. It is more realistic in Bangladesh as there is abundant natural gas in the country and the CNG infrastructures are also available.
g. Electronic fuel injection system to be incorporated in all in-use diesel vehicles. This will substantially decrease the PM emission. Although it involves a considerable cost, but the vehicle owners will be accustomed to it if they can be made aware of the fuel economy with EFI system.
h. All new diesel vehicles should be fitted with turbo-charging and charge cooling system, thus reducing PM and NO_x emissions.
i. The sulfur content of diesel should be lowered form 0.7% by weight to 0.05% in near future. This will significantly reduce the PM emissions. The country should also think of a roadmap of bringing down the sulfur content to 0.005% so that advanced technology in vehicle exhaust treatment could be used. Although Bangladesh Eastern Refinery is not capable to lower sulfur beyond 0.5% it will not be a problem as 75% of the consumed diesel is imported.
j. Two-way 'Catalytic Converter' should be fitted with all new diesel vehicles with immediate effect. This will reduce the PM and HC emission from diesel engines. This is commonly used in industrial countries.
k. 'Trap Oxidizers' can be retrofitted in heavy-duty in-use diesel vehicles, (trucks and buses) to control the PM emissions. This program has been adopted in many developed countries including USA, Germany and Greece and has significantly reduced PM emissions.
l. If possible horizontal exhaust system in trucks, buses, minibuses can be changed to vertical exhaust system, thus reducing the local concentration of pollutants. Retrofitting vertical exhaust in trucks is feasible and is also possible in buses and mini-buses, provided the manufacturers impose no limits.
m. A limit on the vehicle life in terms of mileage and/or year can be imposed to phase out the old vehicles as they generally emit more pollutants and do not allow the use of advanced exhaust treatment technologies.

CONCLUSION

Motorization is the natural consequence of modernization. Emissions from the growing diesel vehicle fleet in Dhaka City coupled with a large number of old and poorly maintained vehicles have exceeded the air-borne pollutant level far beyond the normal standard, posing a serious threat to human health and quality of life of the urban population in greater Dhaka.

Although diesel vehicles constitute only about 20% of all vehicles in Bangladesh, they have a high daily utilization rate. PM emissions from these vehicles have become the critical pollutant for the City population and the city planners as well. Therefore, a deliberate understanding of their emission characteristics and emission control measures would certainly help the authority to take necessary steps in order to mitigate the worsening effects of vehicular pollution in greater Dhaka.

Emission control strategy is guided by socio-economic condition of the country, effective but cheaper technology, presence of emission enforcement infrastructure and above all the sincere desire of government machineries and general population. Considering above factors, some strategies are proposed in this paper, which have already provided effectiveness in emissions control program in many developed and developing countries. If these strategies are sincerely implemented with immediate effect, a cleaner and healthier environment can be presented to the future generations.

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