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CONTROLLING EMISSIONS FROM CONVENTIONAL ROAD TRANSPORTS: DHAKA SITUATION

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ABSTRACT

Vehicular air pollution is the one of the major contributors of air pollution of Dhaka city. This paper reviews the various technologies available for reducing pollution from petrol and diesel run vehicles and makes a comparative assessment of effectiveness of the different methods under the present situation of Dhaka metropolitan city. Control of the pollution created by road transports would require the combination of a pragmatic Emission Standard and its effective implementation. The Standard should be developed on the basis of vehicle data of Bangladesh, the related technical infrastructure at present and the socio-economic context of the country.

Among the emission pollutants Carbon monoxide(CO), Unburned Hydro-Carbon(HC) are mainly contributed by petrol engines and Particulate Matter(PM) and Oxides of Nitrogen(NOx) mainly comes from diesel engines. Manufacturers worldwide are increasingly being forced to improve the emissions from their engines. This may be achieved by using – pre-engine, in-engine and post-engine devices or generally a combination of these. Often there is correlation between the various devices and it is always suggested that the manufacturer specifies the entire set and retrofits often do not produce the same level of pollution control. Among the post-engine devices Catalytic Converter and Diesel Particulate Filters are potential candidates.

Keywords: Air Pollution, Vehicle Emission, Catalytic Converter, Diesel Particulate Filter, Dhaka City .

1. INTRODUCTION

With the increase of vehicle population the emission from road vehicles is increasingly getting attention in Bangladesh. The congested traffic and limited availability of land to build wider roads have worsen the situation in Dhaka. A number of methods are being tried out by the related government agencies to improve the emission from vehicles using conventional fuels. One of such methods is making the use of catalytic converters and diesel particulate filters in road vehicles. The decision of making them mandatory in newly imported as well as old vehicles already in use have opened a debate. This paper identifies the limitations of such post engine emission control devices and evaluate their effectiveness at the present techno-economic situation prevailing for vehicles in Dhaka. Suggestions are made regarding the pragmatic approach of using these post engine devices for effective emission control in Bangladesh context.

2. VEHICLE EMISSION : DHAKA SINARIO

Vehicular emission is one of the major contributors of air pollution of Dhaka city. Emissions from vehicles causes the presence of harmful gases like CO, NOx, unburned hydrocarbon and particulate matters like $PM_{2.5}$ and PM_{10}. Such substances causes a number of diseases (figure-1), specially in a densely populated city. Control of the pollution created by road transports would require the combination of a pragmatic Emission Standard and its effective implementation. The Standard should be developed on the basis of vehicle data of Bangladesh, the related technical infrastructure at present and the socio-economic context of the country.

Pollutant	Origin	Effects
CO Carbon Monoxide	Partially burned fuel	Poisonous to human beings when inhaled. CO adheres to haemoglobin in blood and prevents oxygen being carried to body cells
HC (unburned hydro-Carbon)	Unburned fuel, vaporised fuel escaping from fuel system	Irritates eyes and nose. Cancer risk
C (Carbon)	Partially burnt fuel	Smoke –restriction to visibility. Can carry carcinogenic constituents
NO_x (Oxides of nitrogen – NO, NO_2)	Very high combustion temperature causes nitrogen to combine with oxygen	Toxic to humans. NO_2 combines with water to form nitrous acid, which causes lung disorder. Eye and nose irritant.
Pb (lead)	Added to petrol to raise octane rating	Toxic to humans, causing blood poisoning and nervous disorder

Figure-1: Health hazards from vehicle emissions

It should also take into account the composition of the vehicle population and the contribution of each category to the environmental pollution. The present standard

used was introduced in early nineties, without much serious investigation. This has resulted in unrealistic emission requirements (DOE standard stated in fig-3), which could not have been implemented effectively.

In the situation of Bangladesh at present, after the phasing out of the two-stroke three wheelers finally in January 2003, pollutants from heavy diesel vehicles are the main contributors to environmental pollution[1]. The total number of vehicles plying in Dhaka is about 300,000. The average life of the vehicle fleet in our country is also relatively long, causing the bulk of the vehicles to be relatively old (over 10 years in average). The yearly new registrations is within 5-7 % of the total vehicle population[1] A smaller proportion of newly registered vehicles in imported or assembled new while the majority are vehicles used in developed countries for up to four years[1]. As a result large part of the vehicles are using relatively older vehicle technology.

Fuel used in the country is mainly petrol/octane and diesel. Newly introduced four stroke three wheelers are mainly running on CNG and more than 20,000 vehicles have been converted to CNG operations in the past five years. Since July 2001 the gasoline used is lead-free. The diesel used have a relatively high sulphur content of about 0.7% [2] For economic reasons some practice of fuel adulteration in not uncommon. From July 2003 government agencies have introduced colour codes for fuels like petrol, octane, diesel and kerosene to prevent adulteration of fuels. The effectiveness of the system introduced is yet to be proven.

3. EMISSION CONTROL TECHNOLOGIES

Among the emission pollutants Carbon monoxide(CO), Unburned Hydro-Carbon(HC) are mainly contributed by petrol engines and Particulate Matter(PM) and Oxides of Nitrogen(NOx) mainly comes from diesel engines. Manufacturers worldwide are increasingly being forced to improve the emissions from their engines. This may be achieved by using – pre-engine, in-engine and post-engine devices or generally a combination of these. Often there is correlation between the various devices and it is always suggested that the manufacturer specifies the entire set and retrofits often do not produce the same level of pollution control.

3.1 Catalytic Converter

A catalytic converter (CC) is a post-engine emission control device used in spark ignition engines. It is fitted in the exhaust line and reduces the emission generated by the engine, before being exhausted to the atmosphere. It has no moving parts and inside a converter exhaust gases take part in chemical reactions, in presence of catalyst materials. CC converts polluting gases like CO, NOx and unburned Hydro-Carbon (HC), into CO_2, N_2 and H_2O, which are not pollutants.

Catalytic converters may be classified as 2-way or 3-way Catalytic Converters. A 2-way CC only converts CO and unburned HC into CO_2 and H_2O using oxidizing reactions, while the 3-way CC in addition also reduces NO_X emissions using reducing chemical reactions. Now a days generally 3-way CC are provided with modern automobiles. The reactions only take place in presence of catalyst materials like – Platinum, Rhodium and/or Palladium. In a catalytic converter, large surface area is provided for the chemical reaction to take place and a very small amount of catalyst material is distributed throughout the structure in an ultra-thin layer. Catalytic reactions are generally exothermic so heat-shields and temperature withstanding materials need to used for its construction.

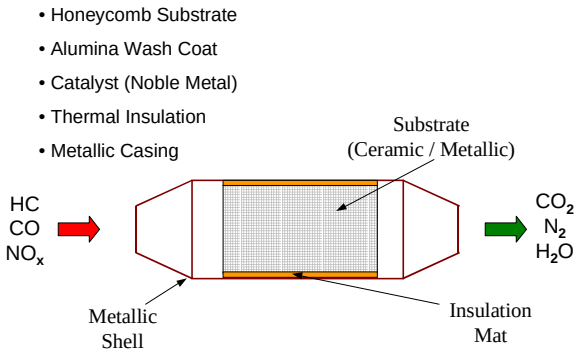

Fig-2. Components of a Catalytic Converter

Generally speaking catalytic converters are very good emission controlling devices achieving more than 90% reduction of the emissions generated by a well tuned modern engine. However it should be understood that this level of performance from a catalytic converter for an economically viable period can be only expected, when a number of prerequisites are met.

Figure-3 shows the comparative performance of exhaust emission measurements of typical HONDA car models with and without built in catalytic converters. The figure also shows typical values of catalytic converter specifications for a typical sedan car.

Honda Civic EK3 1.5 liter 1999

748 rpm		2553 rpm		DOE Standard	
CO	1.65 %	CO	1.19 %	CO	4.0 %
CO_2	12.87 %	CO_2	13.68 %	HC	180 ppm
HC	193 ppm	HC	60 ppm	NOx	600 ppm

Honda CR-V WJ 2.0 liter 1999 with **Catalytic Converter**

749 rpm		2506 rpm	
CO	0.01 %	CO	0.02 %
CO_2	14.65 %	CO_2	14.69 %
HC	35 ppm	HC	8 ppm

- Engine Displacement : 1.5 liter, 2000 cc
- Engine Speed : 2000 - 3000 rpm
- Min. Operating Temp : 250 ºC
- Max. Allowable Temp : 800 ºC
- Maxm Allow Back Pressure : 2 psi
- Fuel Specification : Unleaded, S-content
- Maxm Pollutant in Intake : HC, CO, NOx, A/Fratio
- Pollutant Reduction Efficiency : 70% of HC, CO
- Expected life : 100,000 km

Fig-3 : Performace and Specification of a Typical CC

The degree of emission control stated by the manufacturer can only be attained for a economically viable life period of a catalytic converter only when the engine operates properly. The 3-way catalytic converters incorporated in modern engines essentially require an electronic fuel injection system (EFI), as it is only effective when the air-fuel ratio can be controlled very precisely near stoichiometric. It requires a hot working temperature of about 300°C, for the chemical reaction to start with and a maximum temperature limit of about 800°C[3]. Hence the placement of the catalytic converter in the exhaust line does influence its performance. The fuel used necessarily needs to be lead (Pb)-free, otherwise the catalysts get ineffective (fouling) and the reactions do not take place. Presence of lead in fuel drastically reduces the effective working life of a catalytic converter. Adulteration of fuel also may cause the same problem. There is a specified level of pressure drop across the CC as the gases pass through it (back pressure), for a clogged CC this could significantly reduce the engine performance. It should be realised that a CC is designed to remove the pollutant from a certain flow rate of incoming gases, which are within a certain pollutant level. Hence it is essential to make sure that the engine itself has the fuel control technology and operates in a well maintained condition.

As shown in figure 4a, unburned fuel due to incorrect air-fuel mixture causes overheating and initial melting of monolith (honeycomb). Incorrect air-fuel mixture or a faulty ignition system may cause after-burn of fuel inside a catalytic converter causing overheating and severe thermal stresses breaking or melting monolith, as shown in figure 4b[4].

Fig-4a. Melting of CC due to overheat

Fig-4b. Damaged CC due to after-burn of fuel

Drops of lubricating oil may causes melting of monolith at the entrance, clogging the catalytic converter[4]. Monolith destruction due to mechanical damage (contact with road surface). Broken pieces can choke the exhaust. These are shown in figure 4c and 4d.

Fig-4c. Lubricating oil causing melting at the entrance

Fig-4d. CC damage due to mechanical breakage

It also should be noted that manufacturing and quality control of catalytic converter involves fairly high level of technology, which is beyond the present manufacturing infrastructure of Bangladesh. Hence we will have to rely on import of CC using foreign currency for some time.

3.2 Diesel Particulate Filters (DPF)

Used mainly to reduce PM emissions from diesel engines

It consists of :

- Metallic Casing
- Substrate (Cordierite/SiC)
- Regeneration system
- Monitoring system

Other systems need to be used to reduce HC, CO and NO_x emissions

DOC system SCR System EGR System

Fig-5. Components of a Diesel Particulate Filter

Diesel Particulate Filters (DPF) and Diesel Oxidation Catalyst (DOC) are post-engine devices used to reduce the pollutants from the diesel engine. Particulate matter (PM) and NOx are the main diesel engine pollutant, while the formation of CO is much less due to greater

ratio of air used with the fuel. Among the diesel pollutants DPF is used to remove the Particulate matters (PM) emitted from the diesel engine. It works like a mechanical filter trapping PM present in the exhaust, as the gases pass through it. Unfortunately like any mechanical filter it gradually gets clogged with PM and unburned HC materials and needs to be cleaned up. Otherwise this increases the pressure drop across the filter eventually stopping the engine operation, as the exhaust can not pass through it. This cleaning process is called the 'Regeneration' of the filter. A number of different technologies are used in different engines for performing the regeneration operation, along with necessary instrumentation to sense and control when to start and stop the regeneration process[5,6].

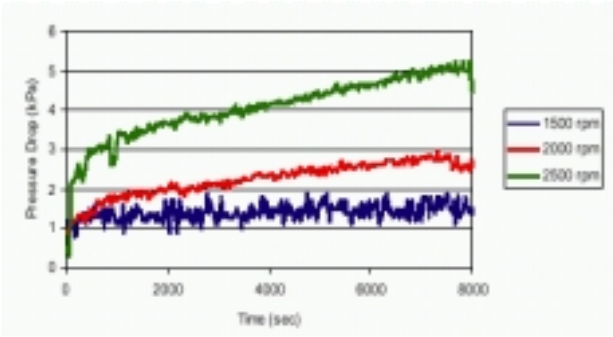

Fig-6. Effect of particulate accumulation on pressure drop across a typical diesel particulate filter

Figure 6 shows the variation of pressure drop across a DPF with time at differenr engine speeds with a 2.4 litre diesel engine[6]. DPF shows good performance in controlling PM emission but very limited effect on HC, NO_X or CO emissions.

3.3 Diesel Oxidation Catalyst (DOC)

Diesel Oxidation Catalyst (DOC) are used to reduce the other pollutants like HC, NO_X and CO level. It is more like a catalytic converter for a diesel engine. Similar to CC it also uses similar chemical catalysts (Platinum, Palladium) to activate chemical reactions reducing HC and CO pollution level of a diesel engine. DOC have limited effect on PM control. For being effective for all of the major pollutants a combination of devices are being used by different manufacturers. In this effort additional features like Continuously regenerative Traps (CRT), Selective Catalyst Reduction (SCR), Diesel particulate NOx Reduction (DPNR) etc. are being developed for cleaner diesel engines. Incorporation of such developments will be necessary to achieve the EURO 4 emission requirements[5,6].

For effective operation DOC essentially needs ultra low sulphur contents (less than 0.05%) in the diesel fuel used. This is due to the fact that diesel oxidation catalysts are much more prone to detrimental effect due to presence of sulphur in the fuel than catalytic converters used in gasoline engines. Diesel engines have lower and relatively less controllable exhaust gas temperature and generally do not operate with as rich as a stoichiometric mixture. The sulphate formation by oxidising catalysts do not go through enough regeneration process at lower exhaust temperatures. The remaining sulphates hampers the effective NO_x reduction significantly. Lower sulpher content is also desirable in gasoline, but a more complete regeneration process of sulphates above 500C, limits the detrimental effects of sulphur[7].

Any one of the DPF/DOC technologies mentioned above is still not in a fully proven state and various technologies or a combination of them are still being tried out in different countries of the world. A comparative picture of different technologies commonly in use is given in figure7[5].

Various technologies are being developed for diesel emission control

DPF

DOC

CRT = DOC+DPF

SCR

SCRT= CRT+SCR

Technology	Control Capability, %			
	CO	HC	NOx	DPM
Diesel oxidation catalyst	>90	>90	n/a	>25
Diesel particulate filter	n/a	n/a	n/a	>90
SCR catalyst	>50	>70	80	>30

Fig-7. Comparative performance of various emission control systems for diesel engines

4. STEPS FOR EFFECTIVE EMISSION CONTROL IN BANGLADESH

The first step for emission control from vehicles using conventional fuels like petrol and diesel is to set a emission standard which can be implemented in Bangladesh. Using alternative cleaner fuels like CNG LNG and LPG can have very significant effect on the emission situation. For such changes vehicles need to be converted for these alternative fuels and the fuel supply infrastructure needs to developed first. Regarding emission from engines using conventional fuels, truly speaking, setting a proper standard and developing the mechanism for ensuring its implementation have been the main problem of effective emission control in Bangladesh, rather than the available emission control technologies. We really are not in a state to compare the appropriateness of related technologies. Bangladesh should have two sets of emission standards – one for vehicles already in use and another for vehicles to be newly registered. The emission limits for the in-use vehicles can be in accordance to the present standard and should take into consideration the diversity of engine technology accumulated in the present fleet (eg. carburettor, electronically controlled carburettor, EFI,

MPFI). The limits set should be achievable through proper engine maintenance and using proper fuel/oil, making it economically viable for the country. The government has already started working in this line for the last couple of years through the Air Quality Management Project (AQMP) with the help from the World Bank.

The emission limits for the vehicles to be newly registered should be significantly more stringent, allowing only vehicles with modern technology to be imported (new/used). Using manufacturer specified post engine emission control devices as well as proper fuel and engine maintenance should be able to achieve and maintain this level of emission for a viable vehicle life. Since the road condition, fuel quality and maintenance facilities in Bangladesh are not up to the standard of developed countries – both new and used/reconditioned vehicles should satisfy the same procedure and frequency of emission tests. This will gradually improve the emission performance of the entire fleet in a sustainable way in near future.

The emission test procedure should be very well defined and test results well documented. Procedures should be developed on the basis of – equipment, manpower, cost and time involved, to make it practically achievable. In addition to Bangladesh Road Transport Authority (BRTA), the testing procedure can be decentralized to a number of licensed test facilities at suitable locations, to make the work load manageable. The performance of the licensed facilities will be monitored by a central body with enough authority to act. A central database will account for all tests carried out at decentralized facilities allowing dynamic supervision and auditing.

No post engine emission control device will work effectively for an economically viable period, unless the engine is producing pollutants with its specified limits. A catalytic converter will never produce desired performance unless the combustion in the engine is going on properly. The cost involvement, complexities associated with retro-fitting[4] and the present sulphur contents of diesel used in Bangladesh, makes the use of DOC/DPF unlikely to be viable in near future. In Bangladesh perspective the proper maintenance of vehicles and their appropriate fitness certification is a much more pragmatic and cost effective approach for emission control. Retrofitting catalytic converters or diesel particulate filter technology in these vehicles is not pragmatic from technical or economic point of view. However considering the long term development of environment quality and the additional cost involved, - the use of catalytic converter in newly imported gasoline-fuelled vehicles is worth of consideration.

In addition steps need to be taken in parallel to reduce adulteration tendency of fuel. Competitive fuel prices at home and abroad and preventing large scale unauthorized transportation of fuel can play an important role in this regard.

Training the vehicle drivers regarding proper driving skills and regular maintenance of the engine can ensure good emission. An authentic driving license issuing mechanism need to be implemented. The process may combine - skill of driving, knowledge of regular engine/vehicle checkups and traffic rules.

5. CONCLUSION

For effective control of emissions from road vehicles using conventional fuels – setting a realistic emission standard and development of the mechanism ensuring its implementation is mainly needed. Regarding the emission standards especially for the in-service vehicles, quality of emission control technology is not the main problem, it can be attained using a number of technologies. Rather operating the engines with proper maintenance is much more pragmatic, for getting lower pollution in a cost-effective way. To ensure this we should concentrate on the development of the annual vehicle fitness certification process, rather than retro-fitting post engine devices at the expense of foreign currencies. In addition steps need to be taken to ensure quality of the fuel and lubricating oil used and better training of the vehicle drivers regarding regular engine maintenance.

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