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POLLUTION ASPECTS OF EMISSIONS FROM SMALL TWO-STROKE AUTOMOBILE ENGINES

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ABSTRACT

Air pollution is becoming very serious problem in front of mankind. The significant environmental implications of vehicles cannot be denied. The need to reduce vehicular pollution has led to emission control through regulations in conjunction with increasingly environment-friendly technologies. In this paper attempt has been made to understand the air pollution problem due to two-stroke engines, which is major cause of main diseases like cancer, heart disease, etc. especially in urban areas. Important pollutants from two-stroke engines along with their effect on environment and on human beings is discussed. To reduce emission from two-stroke engine factors exacerbating are elaborated.

INTRODUCTION

Air pollution is increasing in many parts of the world. The share of two-stroke engine vehicles to vehicular emissions of particulate matter (PM), HC and CO is calculated at 29%, 73% and 42% respectively (Environmental Pollution (Prevention and Control) Authority for National Capital Region 1999). Emissions from large and rapidly growing number of two and three wheeled vehicles are a major source of air pollution in a number of countries, especially in Asia. The inexpensive two-wheelers form a staggering 75-80% of the traffic in most Asian cities. (Roychowdhury 2004). Two-wheel vehicles, which include mopeds, scooters, and motorcycles, are used mostly for personal transportation, although in some cities, they are used as taxis. Three-wheel vehicles, which include small taxis such as auto rickshaws and larger vehicles that hold as many as a dozen passengers, are used commercially. Conventional two-stroke engines have several advantages over four-stroke engines. These include lower cost, excellent power, mechanical simplicity (fewer moving parts and resulting ease of maintenance), lighter and smaller engines, etc.) High hydrocarbon emissions result in part from the scavenging process used by two-stroke engines. Scavenging refers to the process by which combustion products from the previous cycle are forced or scavenged from the cylinder with this new air/fuel charge. Unfortunately, the exhaust ports are also open at this time, allowing 30-40% of the fuel to be lost directly into the exhaust stream. At idle conditions the losses can be as high as 70% (Macro 1998).

Emissions are by-products of the combustion, which mainly contain obnoxious gases and unburnt hydrocarbons. They constitute a hazard to the health and are expensive, because of having unburnt hydrocarbons, i.e. unutilized energy. Carbon monoxide is toxic to humans and animals. The combination of unburnt hydrocarbons and nitrogen oxides, particularly in sunlight, produces visible smog, which is harmful to lungs and eyes. The nitrogen oxides are said to contribute to the depletion of the ozone layer in the upper atmosphere, which potentially alters the absorption characteristics of ultraviolet light in the atmosphere and increases radiation hazard on the earth surface. A fresh, considerably more stringent set of norms are laid down for the year 2000 as shown in Table 1**.** They do not, however, provide standards to control particulate emissions nor do they distinguish between a four-stroke and a two-stroke one. But they do distinguish between a two-wheeler and three-wheeler providing a relaxation in CO emissions in a three-wheeler.

These standards pose a big challenge to the auto manufacturing industry. The application of direct in-cylinder fuel injection (or direct injection, DI) can be used to reduce HC and CO emissions by over 70% (Bryan Willson 2002). The DI technology reduces fuel consumption by approximately 35% and dramatically reduces particulate emissions. If one technology exemplifies the need to overhaul air pollution laws, especially in the large cities in India, it is the two-stroke engine.

EXHAUST POLLUTANTS FROM TWO-STROKE ENGINES

The mixture entering the engine consists of air and fuel. The air consists of 79% nitrogen, 20% oxygen and the remaining is a mixture of other gasses. Fuel consists of hydrocarbons, i.e., long chains of carbon and hydrogen atoms. The heat of compression and spark causes the hydrocarbons to oxidize. Hydrogen merges with oxygen to form H_2O. Carbon merges with oxygen to form CO_2. In the ideal engine the exhaust would consist of H_2O and CO_2. Nitrogen should pass through with no changes. However, the ideal engine does not exist. Some hydrocarbons pass through unburned. Some of the carbon begins to oxidize, but does not come in contact with oxygen to complete the combustion process. The result is harmful emissions. High combustion temperatures cause nitrogen to oxidize creating NOx.

Hydrocarbons: Hydrocarbon emissions result when fuel molecules in the engine do not burn or burn only partially. Following are the reasons for formation of hydrocarbon emissions in two-stroke engines.

- Fresh charge loss during scavenging
- Ignition problems
- Engine mechanical problems
- Carbon build-up
- Combustion chamber design
- Fuel becomes trapped wherever there is an edge around the piston rings and where the head meets the cylinder deck.
- Fuel evaporation

Carbon monoxide: Carbon monoxide results from incomplete combustion of fuel and is emitted directly from vehicle tailpipes. Incomplete combustion is most likely to occur at low air-to-fuel ratios in the engine. These conditions are common during vehicle starting when air supply is restricted (choked), when two and three wheelers are not tuned properly. Nationwide, two-thirds of the carbon monoxide emissions come from transportation sources, with the largest contribution coming from highway motor vehicles. In urban areas, the motor vehicle contribution to carbon monoxide pollution can exceed 90 percent.

Nitrogen oxides (NOx): Under the high pressure and temperature conditions in an engine, nitrogen and oxygen atoms in the air react to form various nitrogen oxides, collectively known as NOx. Nitrogen oxides, like hydrocarbons, are precursors to the formation of ozone. They also contribute to the formation of acid rain.

Particulate emission: Recently it has been reported that two-stroke engines emit significant quantities of particulate emission. Particles are composed largely of unburned or slightly oxidized hydrocarbons,

Table 1: Emission norms for two and three-wheelers.

	Emission Norms (g/km)		
Two-Wheelers			
Year	CO	HC	HC + NO_x
1991	12 - 30	8 - 12	-
1996	4.50	-	3.60
2000	2.00	-	2.00
2005(BS II)	1.50	-	1.50
Three-Wheelers			
(g/km)			
Year	CO	HC	HC + NO_x
1991	12 - 30	8 - 12	-
1996	6.75	-	5.40
2000	4.00	-	2.00
2005(BS II)	2.25	-	2.00

which are emitted during scavenging as well as irregular combustion at idle or low load operation. The particulate matter data obtained after conducting tests on in-use-three wheelers by ARAI (Automotive Research of India) in the year 2000 is significantly higher than that of 1970s. It is observed that the particle diameter was about 150nm for lowest speed, and 90nm at full speed (Patschull & Roth 1994).

Carbon dioxide: In recent years, the U.S. Environmental Protection Agency (EPA) has started to view carbon dioxide, a product of perfect combustion, as a pollution concern. Carbon dioxide does not directly impair human health, but it is a greenhouse gas that traps the earth’s heat and contributes to the potential for global warming.

AIR TOXICS FROM MOTOR VEHICLES

Some toxic compounds are present in gasoline and are emitted to the air when gasoline evaporates or passes through the engine as unburned fuel. Benzene, for example, is a component of gasoline. Two wheelers emit small quantities of benzene in unburned fuel, or as vapour when gasoline evaporates.

A significant amount of automotive benzene comes from the incomplete combustion of compounds in gasoline such as toluene and xylene that are chemically very similar to benzene. Like benzene itself, these compounds occur naturally in petroleum and become more concentrated when petroleum is refined to produce high-octane gasoline. Formaldehyde and acetaldehyde are formed through a secondary process when other mobile source pollutants undergo chemical reactions in the atmosphere.

Hydrocarbons react in the presence of nitrogen oxides and sunlight to form ground-level ozone, a major component of smog. Ozone irritates the eyes, damages lungs and aggravates respiratory problems. It is most widespread and intractable urban air pollution problem. A number of exhaust hydrocarbons are also toxic, with the potential to cause cancer.

Carbon monoxide enters the bloodstream through the lungs and forms carboxyhaemoglobin, a compound that inhibits the blood’s capacity to carry oxygen to organs and tissues. Persons with heart disease are especially sensitive to carbon monoxide poisoning and may experience chest pain if they breathe the gas while exercising. Infants, elderly persons and individuals with respiratory diseases are also particularly sensitive. Carbon monoxide can affect healthy individuals, impairing exercise capacity, visual perception, manual dexterity, learning functions, and ability to perform complex tasks.

There is actually nothing wrong with the two-stroke technology. It is the way people treat their vehicles that create the problem. Two-strokes allow for greater misuse. Because of the way they are built they require less maintenance, but the owners tend to read it as no-maintenance vehicles, and use inappropriate amount and type of lubricating oil. The problem of maintenance is particularly severe when drivers lease their vehicles, because neither the driver nor the owner feels responsible for the mechanical condition of the vehicle.

FACTORS EXACERBATING EMISSION

Poor vehicle maintenance, the misuse of lubricant, the adulteration of gasoline and the lack of catalytic converters exacerbate two-stroke engine emissions. The age and poor maintenance of many two and three-wheelers in the region increase emissions well above any applicable standards. In addition, many drivers use lubricants and fuels of poor quality.

Misuse of lubricant: Two-stroke engines use the "all loss lubrication" system which leads to formulation of emission of smoke and particulates. The problem is further enhanced because three-wheeler drivers tend to use excessive oil of poor quality. If just these things could be controlled, the pollution levels can drop drastically. Delhi banned the sale of loose lube oil, and made it compulsory for it to be pre-mixed with petrol, ensuring that they use the right quantity and quality. Both, the quantity and quality of lubricant used, affect the level of hydrocarbon and particulate emissions from two-stroke engines. Vehicle manufacturers recommend adding 2% lubricant for two-wheelers and 3% lubricant for three-wheelers. But many drivers of three wheelers add considerably more lubricant for several reasons.

- Lack of knowledge about the correct amount of lubricants to be used.
- Addition of excess lubricant to gasoline by filling station attendants at the point of sale.
- Perception that more lubricant will provide greater protection against piston seizure.
- Lower miscibility of straight mineral oil and conventional motor oils with gasoline compared to 2T oil.

Excessive use of lubricant increases combustion chamber deposits and fouls spark plugs. When pistons and rings are badly worn, excess lubricant may postpone piston seizure for a while. But the adverse social effects of much higher emission far outweigh the benefits to vehicle owners. Lubricant requirements for two-stroke engines differ from those for four-stroke gasoline engines; viz., good lubricity, piston cleanliness; low deposits, especially in the exhaust system, and low smoke emission. Two-stroke engine vehicles should use specially formulated 2T oil. Because polyisobutene of moderate molecular weight tends to decompose without leaving heavy deposits, polyisobutene thickener in a base stock is increasingly used in lubricant. Instead, straight mineral oil or new or recycled engine oil, is used which results in greater deposit buildup and higher emissions. The principal reason for using these oils is their lower cost, although some drivers may be under the impression that these more viscous oils provide greater engine protection. Increasing the concentration of lubricant from 3 to 8 percent increases emissions by 61 %. Using straight mineral oil instead of 2T oil increases emissions by about the same amount. Using gasoline from Dhaka rather than the gasoline purchased in India increased emissions by 14 percent (Ken Gwilliam et al. 2004).

Inadequate vehicle maintenance: Vehicular emissions are exacerbated by the age of the vehicle fleet and the poor state of vehicle maintenance (ARAI 1998). A study in the United States found that poorly maintained vehicles, which represented 20% of all vehicles on the road, contributed about 80% of total vehicular emissions. Recently three baby taxis in Dhaka, Bangladesh, from four to seven years old were randomly selected for mechanical inspection. The engineers, inspecting the engines, found evidence of considerable ad hoc, unauthorized repairs and modifications. A combination of inadequate or improper maintenance and repairs by poorly trained mechanics contribute to the poor mechanical state of many vehicles in South Asia.

Emissions by all gasoline vehicles are exacerbated by adulteration of gasoline with kerosene. Kerosene has a higher boiling point than gasoline and is more difficult to burn. As a result more deposits buildup in the engine and more unburned hydrocarbons are emitted in the exhaust gas. Anecdotal evidence suggests that adulteration of gasoline is widespread in South Asia because of the significantly lower retail price of kerosene. Limited sampling and testing of gasoline by the World Bank in Dhaka in 1998 also indicated that a significant fraction of gasoline had been adulterated.

ROAD AND TRAFFIC MANAGEMENT

Inadequate and poor quality of road surface leads to increased vehicle operation costs and also increased pollution. It has been estimated that improvements in roads will result in savings of about 15% of vehicle operation costs.

Lack of catalytic converters: Catalysts deactivate more rapidly in two-stroke engine vehicles, partly because of higher exhaust gas temperature, and need to be replaced frequently. The tendency of two-stroke engines to misfire under low load conditions further aggravates the problem of catalyst deactivation. Despite these limitations of oxidation of catalysts, which lower the emission levels of hydrocarbons and carbon monoxide and to some extent the amount of fine particles emitted in the form of oil droplets, these converters are installed in all new two-stroke engine two and three-wheel vehicles in India. India is considering minimum catalyst durability requirements.

For three-wheelers in South Asia, which are often driven up to 120 kilometres a day, 15000 kilometers is equivalent to less than six months of operation. For a vehicle driven 10 years or more, as many two-stroke vehicles in South Asia are, the catalyst might have to be replaced up to 20 times to maintain the original level of particulate emissions. This is clearly a problem. In India the Society of Indian Automobile Manufacturers (SIAM) is offering the government a warranty of 30,000 kilometers for all two and three-wheelers equipped with catalytic converters.

The emissions that come out of a vehicle depend greatly on the fuel that goes into it. Consequently, programmes to control air toxics pollution have centered around changing fuel composition as well as improving vehicle technology or performance. One of the first, and most successful programs has been the removal of lead from gasoline. The removal of lead from gasoline has essentially eliminated mobile source emissions of this highly toxic substance. Besides the above mentioned factors, the following points should be taken into account to reduce emissions from two-stroke engines.

- Reformulated gasoline
- Limits on gasoline volatility
- More stringent standards and test procedures
- Control of emissions in actual customer use

In summary, the many vehicle and fuel changes in the last 25 years have greatly reduced air toxics emissions from highway vehicles. Overall air toxics emissions will continue to decrease through the 1990s as older vehicles leave the fleet and as new regulatory programmes take effect. However, the number of vehicles on the road and the number of miles they travel is continuing to grow. Without additional controls, growth in vehicle travel will offset progress in reducing air toxics by early in the next century.

Expansion of existing regulatory programs (such as more widespread use of reformulated gasoline or wider requirements for emission inspections) could also help reduce air toxics. Specific vehicle emission standards for one or more toxic compounds are also an option. Changes in gasoline fuel composition (such as reducing sulphur, benzene or other aromatic chemical compounds) can also reduce air toxics emissions. A switch to alternative, non-petroleum fuels that are cleaner than today's gasoline and diesel fuels offers another strategy for reducing air toxics. Choices include alcohols, natural gas, propane and electricity. These fuels are inherently cleaner than conventional gasoline and diesel because they do not contain toxics such as benzene. In addition, they are made of simpler chemical compounds, which yield lower levels of complex combustion byproducts such as 1,3-butadiene.

CONCLUSION

Providing citizens with clean air will ultimately become as clear and important a mandate as providing clean water or effective sewers. No big city can prosper without decent sanitation systems because the consequences are too ugly and too apparent. But as the epidemiology of air pollution grows ever more convincing, the public will demand the same standards for the air, and public officials will have to deliver. Advanced technologies like direct injection and use of catalytic converter can solve the air pollution problem and substantially help reduce greenhouse gases. But auto companies will not push those technologies without unambiguous signals from public officials, and piecemeal regulation is insufficient. In fact, as auto fleets grow, current air pollution laws will only slow the rate at which the air becomes dirtier. Those officials charged with cleaning the air and protecting the public health must take a more aggressive, holistic and longer-term view of the world, and build a system that can actually win the day. Clearly, we can slash pollution and energy consumption; equally clearly, today's air quality and energy rules are not up to the task. Courage and vision can change that.

REFERENCES

Roychowdhury, Anumita 2004. Environmental Health Perspectives, Vol. 112.

ARAI (Automotive Research Association of India.) 1998. Monitoring of in-use vehicle emissions. Paper presented at the Workshop on Integrated Approach to Vehicular Pollution Control, April 16-18, Delhi, India.

Environment Pollution (Prevention & Control) Authority for the National Capital Region 1999. Proposal for emission controls on petrol two-stroke engine driven two and three wheelers and other issue, October, 1999.

Bryan Willson, 2002. Direct injection as a retrofit strategy for reducing emissions from 2-stroke cycle engines in Asia. Better Air Quality Asia Conference.

Ken Gwilliam, Masami Kojima and Todd Johnson 2004. Reducing Air Pollution From Urban Transport. Report of the International Bank for Reconstruction and Development.

Marco Nuti, 1998. Emissions from Two-Stroke Engines, Society of Automotive Engineers, p. 85.

Nathan Lorenz, Tim Bauer and Bryan Willson 2005. Design of a Direct Injection Retrofit Kit for Small Two-Stroke Engines. Society of Automotive Engineers of Japan.

Patschull J. and Roth P. 1994. Measurement and reduction of particles emitted from a two-stroke engine. SAE 941683.