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Analysis of Exhaust Emission of Vehicles in Dhaka City of Bangladesh

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Abstract - Mega cities in South Asia are an epitome of traffic snarls and resulting vehicular pollution. Dhaka, a center of polity and economy in Bangladesh, is no exception. This study is focused on the measurement of air pollution levels at traffic congestion and road in Dhaka City. The aim of this paper is to discuss the vehicle engine emissions and the technologies and methodologies available to help reduce these emissions. It has been revealed that the pollution level at traffic congestions has considerably improved due to the large scale introduction of CNG vehicles in Dhaka city. Vehicle exhaust emission level assessment data show that Dhaka city is exposed to high concentration of CO, NO_x and SO_x. Some recommendations for air pollution control in Dhaka city are also incorporated in the paper.

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Analysis of Exhaust Emission of Vehicles in Dhaka City of Bangladesh

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Abstract - **Mega cities in South Asia are an epitome of traffic snarls and resulting vehicular pollution. Dhaka, a center of polity and economy in Bangladesh, is no exception. This study is focused on the measurement of air pollution levels at traffic congestion and road in Dhaka City. The aim of this paper is to discuss the vehicle engine emissions and the technologies and methodologies available to help reduce these emissions. It has been revealed that the pollution level at traffic congestions has considerably improved due to the large scale introduction of CNG vehicles in Dhaka city. Vehicle exhaust emission level assessment data show that Dhaka city is exposed to high concentration of CO, NO_x and SO_x. Some recommendations for air pollution control in Dhaka city are also incorporated in the paper.**

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I. Introduction

Dhaka one of the mega cities of the world, witnessed a very fast growth of urban population in recent times. Air pollution in Dhaka city is reported to be serious and damaging to public health. In the winter of 1996-97, air pollution of Dhaka city became the severest when lead in the air was reported higher than in the atmosphere of any other place of the world. Concern over air pollution rate of Dhaka city ultimately led to the promulgation of National Ambient Air Quality Standards in Bangladesh in 1997.

A study of impact of auto-exhaust on air quality of Dhaka city has been conducted in the year 2000, it is revealed that traffic congestion, fuel quality and brick field emission are the main reasons of air pollution in Dhaka city. To control air pollution level, CNG at large scale has introduced in Dhaka city. Deterioration of air quality is a major environmental problem in many large urban centers in both developed and developing countries. In our modern society, quality of life is greatly measured by the amount of consumption of electricity or by the use of car. Electricity generation and operation of vehicles mostly use fossil fuel. As these fuels are burnt, huge quantity of lethal chemicals and poisonous particulate matter are released as a part of emission into the surrounding atmosphere due to incomplete combustion causing serious air pollution, affecting public health. The auto exhaust affects our valuable cultural heritage, historical places, monuments, architecture and the environment. Meteorological and topographical conditions affect dispersion and transport of these pollutants in ambient air.

As people spend most of their time indoors and the concentrations of pollutants may build up in an enclosed space, the risk to health may be greater to exposure to air pollution indoor than outdoor.

Reduction of PM_{10} concentration in Dhaka by 20% would result in avoiding 1200 deaths, 80 million cases of sickness and a health cost savings of US$169.00 million. If PM_{10} concentration could be further reduced by another 80%, then that would result in avoiding of 3500 deaths, 235 million cases of sickness and resulting in a health cost savings of US$492.00 Million. But all these estimates need to be given a sound basis by detailed and scientific studies on an urgent basis. So, the emission analysis and reduction technology should implement in our country to reduce exhaust emission.

II. Combustion in Internal Combustion Engine

The internal combustion engines are those engines in which the combustion of the fuel takes place inside the engine cylinder. The distinctive feature of the I.C engine is that combustion and conversion of heat energy into mechanical work occur inside a cylinder. These engines are noted for their high overall efficiency and low operating cost, lightweight and compactness and constant readiness for starting. Exhaust emission from internal combustion engine is the major source of air pollution.

Combustion Stoichiometry means relations between the composition of the reactants (fuel and air) of a combustible mixture and the composition of the products. These relations depend only in the conservation of mass of each chemical element in the reactants.

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The overall complete combustion equation is-

$$C_a\ H_b + (a + \frac{b}{4})\ (O_2\ +\ 3.773N_2) = aCO_2 + \frac{b}{2}\ H_2O\ +\ 3.773\ (a + \frac{b}{4})\ N_2 \quad (1)$$

Let, the fuel is octane C_8H_{18}. Equation becomes-

Fuel Air Products

$$C_8H_{18} + 12.5\ (O_2 + 3.773N_2) = 8\ CO_2 + 9\ H_2O + 47.16\ N_2 \quad (2)$$

In moles:

$$1 + 12.5\ (1+3.773) = 8+9+47.16$$
$$1 + 59.66 = 64.16$$

Relative mass:

$$114.15+59.66\times28.96 = 8\times44.01+9\times18.02+47.16\times28.16$$
$$114.15 + 1727.8 = 1842.3$$

Per unit mass fuel:

$$1 + 15.14 = 16.14$$

For stoichiometric combustion, 1 mole of fuel requires 59.66 moles of air and produces 64.16 moles of products. The stoichiometric $\left(A/F\right)_s$ is 15.14 and $\left(F/A\right)$ is .0661.

III. Pollutions from Internal Combustion Engine

Emission from vehicles especially automobiles contribute significantly two-third of air pollution in the urban area.

a) Major pollutants emitted from gasoline fueled vehicles

i. CO: Carbon monoxide is colorless and odorless gas, slightly denser than air that is very harmful for environment.

ii. HC: Hydrocarbon Compounds consisting of carbon and hydrogen and include a variety of other volatile organic compounds (VOCs).

iii. NO_x: Nitrogen oxides (NO_x) include nitric oxide (NO), nitrous oxide (N_2O), nitrogen dioxide (NO_2), dinitrogen trioxide (N_2O_3) and nitrogen pentoxide (N_2O_5).

iv. Pb: Lead is also emitted from the vehicles which is very harmful for human health.

b) Pollutants from diesel-fueled vehicles

i. NO_x: Nitrogen oxides (NO_x) include nitric oxide (NO), nitrous oxide (N_2O), nitrogen dioxide (NO_2), dinitrogen trioxide (N_2O_3) and nitrogen pentoxide (N_2O_5).

ii. SO2: Sulfur dioxide is a stable, nonflammable, non-explosive, colorless gas. In the atmosphere, SO_X may be converted to sulfur trioxide (SO_3) by reacting with O_2.

iii. PAH: Motor vehicles emit toxic HC including benzene, aldehydes and polyaromatic hydrocarbons (PAH).

iv. Particulate matter (including smoke): Particulate matter consists of fine solids and liquid droplets other than pure water that are dispersed in air.

IV. Experimental Setup and Procedure

a) Experimental Setup

Figure 1 shows the experimental setup Flue Gas Analyzer.

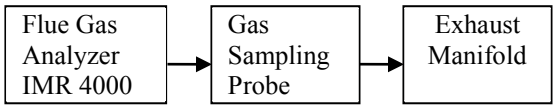

Figure 1 : Experimental setup of IMR 4000 Flue Gas Analyzer

b) Working Procedure

The system should be connected to the mains. Operation via accumulators allows an operating time of eight hours. Gas temperature probe has to connect to the system. Ambient air probe has to connect to the system. Hose has to connect to the port 'GAS Input' at the analyzer. Particle filter should be checked, change if severely polluted. Switch on by flip switch. The probe is not to be in the flue gas as the calibration is done with ambient air. Computer's initialization and zero point-calibration (3 minutes) are displayed. Calibration runs automatically. After that the program changes to the main menu. Failure during calibration will be displayed. The flue gas probe should Place in the stack, looking for the core flow (highest temperature), fixing the probe. The measurement run automatically and continuously, the measured and calculated values are shown simultaneously at the display. Probe should remove from the measurement point and getting the system purged with ambient air, need to wait until the display shows 0 ppm for every component or the oxygen sensor shows 20.95%. Now the system may be switched off.

V. Experimental Data Analysis

The objectives were to collect data from different types of vehicles running inside Dhaka city and to analysis the data by comparing with the standard data. Then, to reach in a conclusion about the present air quality of Dhaka city whether it is on the safe zone or not and recommendations of which steps can be taken.

a) Case study for diesel engine

Firstly, BN Jeep-1165 Land Cruiser was used which has 6 cylinders and is running by diesel as shown in Table I. Three observations had been taken and every observation was taken for average 25 to 30 minutes. Table II shows the various data from diesel engine.

Table i : Engine Specification

Types of vehicles	BN Jeep-1165 Land Cruiser
Cylinder	6
Stroke	4
Fuel Used	Diesel
Run Time	25-30 min (about)

Table ii : Data from Diesel Engine

No. of Obs.	1	2	3
CO_2 max.	5.50 %	15.50 %	15.50 %
Temp. Gas	67 ˚C	70 ˚C	73 ˚C
Temp. Air	30 ˚C	32 ˚C	26 ˚C
O_2	18.17 %	18.10 %	18.05 %
CO_2	0.00 %	0.00 %	0.00 %
CO	50 ppm	50 ppm	52 ppm
CO	57 mg/m³	57 mg/m³	64 mg/m³
NO	86 ppm	83 ppm	83 ppm
NO	105 mg/m³	114mg/ m³	114mg/ m³
NO_2	14 ppm	17 ppm	13 ppm
NO_2	27 mg/m³	32 mg/m³	23 mg/m³
SO_2	1 ppm	0 ppm	0 ppm
SO_2	2.8 mg/m³	0 mg/m³	0 mg/m³
H_2S	0 ppm	0 ppm	0 ppm
H_2S	0 mg/m³	0 mg/m³	0 mg/m³
Lambda	7.54	7.35	7.23
qA	1.57 %	1.66 %	1.91 %
ETA	98.38%	98.33 %	98.08 %

b) Case study for petrol engine

Then Nissan, super 10112 saloon was used which has 6 cylinders and is running by petrol as shown in Table III. For this, three observations had been taken and various data from petrol engine are shown in Table IV.

Table iii : Engine Specification

Types of vehicles	Nissan, super 10112 saloon
Cylinder	6
Stroke	4
Fuel Used	Petrol
Run Time	25-30 min (about)

Table iv : Data from Petrol Engine

No. of Obs.	1	2	3
CO_2 max.	15.50 %	15.50 %	15.50 %
Temp. Gas	149 ˚C	118 ˚C	91 ˚C
Temp. Air	30 ˚C	31 ˚C	33 ˚C
O_2	9.20 %	12.97 %	2.00 %
CO_2	0.00 %	0.00 %	0.00 %
CO	76 ppm	68 ppm	73 ppm
CO	87 mg/m³	77 mg/m³	83 mg/m³
NO	141 ppm	65 ppm	107 ppm
NO	191 mg/m³	80 mg/m³	131mg/ m³
NO_2	0 ppm	0 ppm	0 ppm
NO_2	0 ppm	0 ppm	0 mg/m³
SO_2	0 ppm	1 ppm	2 ppm
SO_2	0 mg/m³	2.8 mg/m³	5.6 mg/m³
H_2S	0 ppm	0 ppm	0 ppm
H_2S	0 mg/m³	0 mg/m³	0 mg/m³
Lambda	1.78	2.63	1.11
qA	3.5 %	4.46 %	2.78 %
ETA	98.47%	98.12 %	98.79 %

c) Case study for CNG vehicles

At last, A CNG vehicle was used. For CNG vehicles only one observation was taken. The specification of CNG engine is shown in Table V. Table VI shows the various data from CNG engine also Table VII shows the revised ambient air quality standards for Bangladesh.

Table v : Engine Specification

Types of vehicles	CNG
Cylinder	1
Stroke	4
Fuel Used	Compressed Natural Gas
Run Time	25-30 min (about)

Table vi : Data from Cng Engine

No. of Obs.	1
CO_2 max.	11.75 %
Temp. Gas	115 ˚C
Temp. Air	34 ˚C
O_2	14.97 %
CO_2	0.00 %
CO	46 ppm
CO	52 mg/m³
NO_2	0 ppm
NO_2	0 mg/m³
SO_2	75 ppm
SO_2	215 mg/m³

Table vii : Revised Ambient Air Quality Standards for Bangladesh

Pollutant	Objective	Averaging Tim
CO	10 mg/m³ (9 ppm)	8-hour
	40 mg/m³ (36 ppm)	1-hour
Lead	0.5 mg/m³	Annual
NO_2	100 µg/m³ (0.053 ppm)	Annual
PM-10	50 µg/m³	Annual
	150 µg/m³	24-hour
PM-2.5	15 µg/m³	Annual
	65 µg/m³	24-hour
Ozone	235 µg/m³ (0.12 ppm)	1-hour
	157 µg/m³ (0.08 ppm)	8-hour
SO_2	80 µg/m³ (0.03 ppm)	Annual

From the above tables it is found that, for diesel engine, the average value of CO is 50.66 ppm which is near to the standard air quality whether it has been taken for 20-25 minutes only. Thus for petrol engine, the average value is 72.33 ppm and for CNG, it is 46 ppm.

And for diesel engine the average value of NO_2 is 14.66 ppm. For petrol engine and CNG, the amount of NO_2 is negligible.

The amount of SO_2 is 1 ppm for diesel engine in observation no. 1 and others are negligible. For petrol engine, the average value is 1 ppm which is negligible. But for CNG, it is 75 ppm.

So it can be said that the exhaust emission of vehicle in Dhaka city that is found in the experiment is in the range of revised ambient air quality standards for Bangladesh.

VI. Conclusions

The problem of traffic congestion and uncontrolled vehicle emissions make life miserable and causing threat to health and economic loss as well. Public transport service and air quality situation of Dhaka City is continuously deteriorating every year and imposing huge cost on the society. Though there is little information on human health, there is clear evidence that the air quality in Dhaka is harmful for the city dwellers and it is causing not only discomfort but also several diseases including allergy and asthma. Such a problem needs immediate attention from the policy makers. As vehicle and emissions is a major contributor to air pollution, it is possible to improve air quality by reducing the vehicle stock through improving the public transport system service. Government should strengthen vehicle emission standards (VES), regulations, enforcement and measures to reduce fuel demand and improve traffic conditions. Improved public transport facilities of the city could solve the transport and congestion problems, as well as improve the air quality.

VII. Nomenclature

A/F	Air fuel ratio
PAH	Poly aromatic hydrocarbons
PPM	Parts per million
PM	Particular matter
VES	Vehicle emission standards

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