Vehicular Pollution, Their Effect on Human Health and Mitigation Measures

[1]Udit Goel, [2]Sajtih Sathyan, [3] Dr. Nihal Anwar Siddiqui, [4] Prakhar Sachan
[1]Student M.tech HSE, [2]Student M.tech HSE, [3]HOD HSE, [4]Student B.tech FSE
[1]Health Safety and Environment,
[1]University of petroleum and energy studies, Dehradun, India

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Abstract : Emission from vehicles especially automobiles is responsible for about two third of air pollution in the urban area. The major pollutants emitted by motor vehicles including CO, NOx, sulphur oxides, (SO), HC, lead (Pb) and suspended particulate matter (SPM), have damaging effects on both human health and ecology. The internal combustion engines need a mixture of air and fuel to burn and produce energy to propel the vehicle. These burnt gases which come out of the exhaust are responsible for pollution. In petrol engines, the gases comprise a mixture of unburnt hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx). If these gases are in excess quantities, vehicular pollution is caused. Emissions of Diesel vehicles are the concentration of CO and unburnt HC in the diesel exhaust are rather low, both of which are compensated by high concentration of NOx and CO2. There are smoke particles and oxygenated HC, including aldehydes and odour-producing compounds.
This paper initially presents various types of pollution emitted by vehicles, their effect on human health and mitigation measures by the use of various new technologies of Automobile Engineering and Alternative fuels.

***IndexTerms* - Emissions; Air Pollution; Health effects; Mitigation technology; Alternative Fuels**

I. INTRODUCTION

The major sources of air pollution are the flue gases, emission from refineries and factories, etc., on one hand; and exhaust emissions from vehicles on the other hand. The diesel fumes are more carcinogenic. It is believed that cancer potency level of the exhaust from diesel vehicles in India is double that of petrol run vehicles. The risk of diesel fumes is enhanced by their ability to trigger a wide range of non-cancerous effect, including allergy, asthma and other respiratory problems. The unleaded petrol introduced earlier in Delhi for all vehicles to curb air pollution led to a controversy as it was apprehended that unleaded petrol used in vehicles without catalytic converters will emit more poisonous gases like benzene. Lead from automobile exhaust and industry accumulates in the form of dust. City road dust has been found to contain two grams of lead per kilograms of dust. Much worse in inhalation, organic lead emitted from cars, gets easily absorbed in brain, liver, kidney and blood, which becomes cumulative poison leading to brain damage, muscular paralysis, convulsions and even death. For this reason, leaded petrol has been banned in developed countries.

Control over urban air pollution turns out to be an enormous challenge due to not only the rising numbers of total vehicles but also the increased toxic risk of the growing numbers of diesel cars. Diesel cars emit 7.5 times more toxic particulate matter (PM) than comparable petrol cars.

Apparently, many efforts are needed to arouse awareness among the consumers to make their vehicles eco–friendly in order to reduce emissions by means of new and innovative automobile technologies and alternative fuels.

Various Emissions Emitted by Vehicles:-

Pollution from vehicles especially automobiles is responsible for about two third of air pollution in the urban area. Main sources of emission from automobiles are as described below:

SI ENGINE (GASOLINE FUELLED)

CO	.2 to 5% by volume (v/v)
HC	300 to 6000 ppmc1*, v/v
NOx	50 to 2000ppm v/v

CI (DIESEL) ENGINE

CO	.03 to .1%, v/v
HC	200 to 5000 ppmc1
NOx	100 t 2000 ppm
PM	.02 to .2 g/m3 (.2 to .5% of fuel consumption by mass

There are 3 types of emission through which pollutant emitted:-

Crankcase Emission -
Crankcase Emission (also called running loss emissions) is unburnt or partially burned fuel components that, under pressure, escape from the combustion chamber, pass the pistons and enter the crankcase. This mixture is called blow-by. The main constituent of blow-by emission is HCs. If uncontrolled, it may constitute 13–25% of total emissions. Since diesel engines compress only air, blow-by contain very low levels of pollutants.

Evaporative Emissions
Evaporative Emissions HC vapours, lost constantly and directly to the atmosphere due to volatile nature of petrol, mainly from the fuel lines, fuel tank and carburetor depending upon fuel composition, engine operating temperature and ambient temperature. Losses from the carburetor, called Hot Soak Emissions, occur when a hot engine is stopped. It should be noted that, out of total emissions, which is much more in case of petrol than diesel, 20-32% of the total emissions are due to evaporation losses, of which the HCs happen to be the chief constituents.

Exhaust Emission
Automotive exhaust is the major source constituting about 60% of the total emission. Automobile exhaust consists of wide range of pollutants from simple to carcinogenic substances such as (1) Hydrocarbons (Unburnt), (2) Carbon monoxide, (3) Oxides of nitrogen (NOx), (4) Lead oxides, (5) Particulate matters e.g. lead, carbon, alkaline earth compounds, iron oxide, tar, oil, mist (6) Traces of aldehydes, esters, ethers, sulphur dioxide, peroxides, ketones benzene (C6H6), 1, 3 butadiene, Poly Aromatic Hydrocarbons (PAH), metal dust, asbestos fiber, dioxin, furon, ammonia, organic acids , chlorofluorocarbons (CFCs) etc.

Hydrocarbons and CO appears in the exhaust gas products of incomplete combustion. Oxides of nitrogen result from the reaction of nitrogen and oxygen contained in the combustion air at high temperature prevailing during combustion. Further, many of these primary pollutants react with each other to form secondary pollutants. Chief among these includes HC, CO, NOx when mixed with atmospheric water vapours in the presence of sunlight form ozone and variety of complex organic gases and resultant particulates known as Photochemical Smog.

The major pollutants emitted from exhaust emissions of gasoline fueled vehicles are CO, HC, NOx and Pb while pollutants from diesel-fueled vehicles are particulate matter (including smoke), NOX, SO2, PAH. The detailed information of these pollutants is as given below.

Carbon Monoxide (CO) - colorless and odorless gases slightly denser than air. Residence time and turbulence in the combustion chamber, flame temperature and excess O2 affect CO formation. Conversion of CO to CO2 in the atmosphere is slow and takes 2 to 5 months.

Hydrocarbon Compounds (HC) - Compounds consist of carbon and hydrogen and include a variety of other volatile organic compounds (VOCs). Most HCs are not directly harmful to health at concentrations found in the ambient air. Through chemical reactions in the troposphere, they play an important role in forming NO2 and O3 which are health and environmental hazards. Among various HC, methane (CH4) is absent from these reactions. Remaining HC, non-methane hydrocarbons (NMHC) are reactive in the formation of secondary air pollutants. NMHC are photo chemically reactive.

Benzene and Polyaromatic Hydrocarbons (PAH) - Motor vehicles emit toxic HC including benzene, aldehydes and Polyaromatic hydrocarbons (PAH). About 85 to 90% benzene emissions come from exhaust and the remainder comes directly from gasoline evaporation and through distribution losses. Toluene and xylene HC compounds are present in the gasoline whereas aldehydes, 1, 3 butadiene are absent from gasoline, diesel fuel, ethanol or methanol but in their exhaust emissions as partial combustion products. PAH are emitted at a higher rate in exhaust of diesel-fueled vehicles than gasoline –fueled vehicles.

Nitrogen oxides (NOX) - includes nitric oxide (NO), nitrous oxide (N2O), nitrogen dioxide (NO2), dinitrogen trioxide (N2O3) and nitrogen pent oxide (N2O5). NO and NO2 collectively represented as NOX, are the main nitrogen oxides emitted by vehicles. About 90% of these emissions are in the form of NO produced in the vehicle engine by combustion of nitrogen at high temperatures. NO2 formed by oxidation of NO, has a reddish brown colour and pungent odour.

In the atmosphere, NO2 involved in a series of reactions in the presence of UV radiation that produces photochemical smog, reducing visibility. It may also react with moisture to form nitric acid (HNO3) aerosols. In the lower atmosphere (troposphere), NO2 forms O3 by means of reaction with HC, while in the upper atmosphere, it reacts with chlorine monoxide to form chlorine nitrates. In developing countries, the transport sector accounts for 49% of NOX emissions and the power sector, 25%; the industrial sector, 11%; the residential and commercial sectors, 10% and other sources 5%.

Sulphur dioxide (SO_2) - is a stable, non-flammable, non-explosive, colourless gas. In the atmosphere, SOX may be converted to sulphur trioxide (SO_3) by means of reaction with O_2. SO_2 and SO_3 react with moisture in air to form sulphurous (H_2SO_3) and sulphuric (H_2SO_4) acids may precipitate to earth as acid rain. Sulphates may also be produced through reaction of these sulphur compounds with metals present in particulate matter.

Ozone (O_3) - in the lower (troposphere) layer, ground level ozone (GLO) is formed by the reaction of VOCs and NOX with ambient O_2 in the presence of sunlight and high temperatures. GLO is a major constituent of smog in urban areas and motor vehicles are the main emission source of its precursors. The reactions that form GLO also produce small quantities of other organic and inorganic compounds such as peroxyacetyl nitrate (PAN) and nitric acid. GLO concentrations depend on the absolute and relative concentrations of its precursors and the intensity of solar radiation, which exhibits diurnal and seasonal variations. Thermal inversions increase GLO concentrations.

Particulate matter (PM) - consists of fine solids and liquid droplets other than pure water dispersed in air. Total suspended particulates are particles with an aerodynamic diameter greater than 70 μm. PM with an aerodynamic diameter greater than 10 μm known as suspended inhalable particulate matter/Respirable Suspended Particulate Matter (RSPM) or PM10, remains in the atmosphere for longer periods because of its low settling velocity. PM10 can penetrate deeply into the respiratory tract and cause respiratory illness in humans. PM with an aerodynamic diameter of 2.5-10 μm or less is defined as fine particles (PM2.5), while the larger PM is called coarse particles. Nearly all PM emitted by motor vehicles consists of fine particles and a large fraction of these particles has an aerodynamic diameter less than 1micrometer.
PM2.5 can also be formed in the atmosphere as aerosols from chemical reactions that involve gases such as SO_2, NOX and VOC. Sulphates which are commonly generated by conversion from primary sulphur emissions make up the largest fraction of PM2.5 by mass. PM2.5 can be formed as a result of solidification of volatile metals salts as crystals following cooling of hot exhaust gases from vehicles in ambient air as well. Gasoline fueled vehicles have lower PM emission rates than diesel–fueled vehicles. PM emissions from gasoline fueled vehicles result from unburned lubricating oil and ash-forming fuel and oil additives. PM emitted by diesel-fueled vehicles consists of soot formed during combustion, heavy HC condensed or adsorbed on the soot and sulphates. These emissions contain PAH. With the advancement of emission control measures in engines, however, the contribution of soot has been reduced considerably.

Black smoke, associated with the soot portion of PM emitted by diesel-fuelled vehicles, results from the deficiency of O_2 during the full combustion or expansion phase. Blue, grey and white smokes are caused by the condensed HC in the exhaust of diesel-fueled vehicles. Blue or grey smokeresults from vaporized lubricating oil and white smoke occurs during engine start-up in cold weather. Diesel fuel additives such as Ba, Ca and Mg reduce smoke emissions but increase PM sulphate emissions. These additives may also increase PAH emissions.

Dioxins- Cu based additives can reduce PM emissions but may catalyze the reaction between HC and trace amounts of chlorides in diesel fuel to form dioxins which are emitted in the exhaust.

Chlorofluorocarbons (CFCs) - The source of CFC emissions from motor vehicles is the Freon gases used in air conditioners. CFC emitted into the atmosphere rise to the stratosphere layer within 10 years and is estimated to remain there for 400 years. CFC molecules struck by UV radiation release chlorine atoms, which destroy O_3 by the formation of chlorine monoxide. Furthermore, when a free O_2 atom reacts with a chlorine molecule, an O_2 molecule is formed and a chlorine atom is released to destroy more O_3.

Carbon dioxide (CO_2) - is a greenhouse gas associated with global warming, resulting mainly from increased combustion of fossil fuels including motor vehicle fuels. (Source: Dr. G. C. Kisku, Scientist, Nature and type of pollution from automobiles and strategies for its control)

The following table illustrates an idea about the pollution related to the various parts of an automobile.

TABLE 2 AUTOMOBILE PARTS AND POLLUTION PROBLEMS ASSOCIATED WITH THEM

Parts of Vehicle	Problems and Pollution
Battery	Contains lead and HCl
Engine	Waste per ton of castings, 0.3 ton mainly slag's with some toxic contaminants
Exhaust	Contains several air pollutants, 20% NO_2, 23% Hydrocarbons and 45% CO.

Plastic Components	Toxic chemicals used in the production include vinyl chloride, formaldehyde, phenols and several solvents
Tyres	Toxic chemicals used in the production include amines, thiurams, nitrosamines and solvents.

Pollution Hazards and Human Health

The major pollutants emitted by motor vehicles including CO, NOx, sulphur oxides, (SO), HC, lead (Pb) and suspended particulate matter (SPM), have damaging effects on both human health and ecology. The human health effects of air pollution vary in the degree of severity, covering a range of minor effects to serious illness, as well as premature death in certain cases. Most of the conventional air pollutants are believed to directly affect the respiratory and cardio-vascular systems. In particular, high levels of SO2 and SPM are associated with increased mortality, morbidity and impaired pulmonary function. Lead prevents hemoglobin synthesis in red blood cells in bone marrow, impairs liver and kidney function and causes neurological damage.

Pollutants	Effects on Human Health	Effects on the Natural Environment
Carbon monoxide	Can affect the cardio-vascular system, exacer-baiting cardiovascular disease symptoms, particularly angina; may also particularly affect foetuses, sickle cell anaemic and young children. Can affect the central nervous system, impairing physical coordination, vision and judgement, creating nausea and headaches, reducing worker productivity and increasing personal discomfort	
Nitrogen oxides (NOX)	Nitrogen dioxide (NO2) can affect the respiratory system. Nitrogen monoxide (NO) and nitrogen dioxide (NO2), where they play a part in photochemical some formation, may contribute indirectly to increased susceptibility to infections, pulmonary disease, impairment of lung function and eye, nose and thread irritations.	NO and NO2 can contribute significantly to acid deposition damaging aquatic eco-systems and other eco-systems such as forests NOx can also have a fertilizing effect on forests
Sulphur oxides (SO2)	Sulphur dioxide (SO2) can affect lung function.	Sulphur oxides can contribute significantly to acid deposition impairing aquatic and forest ecosystems. Sulphates can affect the perception of the environment by reducing visibility even at low concentrations.
Particulate matter (SPM and RPM)	Fine particulate matter may be toxic in itself or may carry toxic (including carcinogenic) trace substance, and can alter the immune system. Fine particulate can penetrate deeply into the respiratory system irritating lung tissue and causing long-term disorders.	Fine particulate can significantly reduce visibility. High dust and soot levels are associated with a general perception of dirtiness of the environment.
Lead	Can cause brain damage, encephalopathy in children resulting in lower IQ, death, hyperactivity and reduced ability to Constt.	Lead

Mitigation Measures
1) By the use of new and innovative technologies
2) By the use of alternative fuels.
First of all, the new and innovative technologies related to automobiles are in consideration as follows.
1) Mitigation Measures by the Use of New and Innovative Technologies
Crank Case Emission
Crank case emissions can be minimized by providing positive crank case reventilation (Positive Ventilation system). Emission from the exhaust can be controlled by a combination of methods like,
(1)Exhaust gas re-circulation for control of the oxide of Nitrogen,
(2)Catalytic or non-catalytic conversion of hydrocarbons
(3)Oxidation of carbon monoxide and unburnt hydrocarbons in the exhaust system by low pressure air injection into the exhaust port.
(4)Engine modification to reduce the volume of contaminants released from the cylinders.
Evaporative Emission
Emission of fuel vapour from carburetor and fuel tank may be reduced by installing fuel vapour recovery systems. For example, an Evaporative Loss Control Device (ELCD) having been developed by ESSO, can be used.
The vapour-return line which connects the fuel pump to the fuel tank, allows the vapour formed in the fuel pump to return to the fuel tank. At the same time, it permits excess fuel pumped by the fuel pump to return to the fuel tank.
In some cars, a vapour separator is connected between the fuel pump and the carburetor. The vapour formed in the fuel pump enters the vapour separator, as bubbles, along with the fuel. The vapour rises to the top of the vapour separator, from which it is forced due to the fuel pump pressure, to pass through the vapour returning line to the fuel tank.

Exhaust Emissions

1) Control of Oxides of Nitrogen from SI (Spark Ignition) Engine Exhaust

There are several methods to control the oxides of nitrogen (NO2) present in the IC engine exhaust. Basically, there are two ways,
1. By controlling the formation of NOx itself through changing the operating or design parameters or by some device to reduce the peak combustion temperature mainly responsible for the formation of NOx in the combustion chamber and
2. By using a catalyst in the exhaust system to reduce NOx to nitrogen and oxygen after its formation.
3. The other possible methods to control NOx emissions at the sources are
   - Recirculation of the part of the exhaust gas
   - Water injection into the inlet manifold.
   - Charge dilution with some gas like carbon-dioxide, helium, argon, etc.

2) Exhaust Gas Recycling (EGR)

1. It is proved from the experiments that EGR is a promising method to control NOx emission. EGR controlled 81-88% of NOx at 30% recycling.
2. With 30% recycling, there is a fuel penalty of 23.1% to 28% considered to minimize bsfc value increased from 3.85% to 28% when the percentage recycling increased from 10% to 30%.
3. With 30% recycling, as the speed increased from 1200 rpm to 1800 rpm, the loss is maximum power output increasing from 9% to 13.5% and from 1.88% to 13.5% in the recycling range of 10% to 30%. Even with 20% recycling, the loss is maximum and power is high as 31.8% with running at 2400 rpm.
4. The rate of reduction of NOx emission is much faster at higher speeds with increase in percent recycling.
5. The peak exhaust temperature increases with the rise in percent recycling as well as speed.
6. Exhaust gas recycling helps in the reduction of carbon monoxide emission as well.

3) Diesel Smoke

1. Black Smoke: It is a suspension of spot particles in the exhaust gases and results from incomplete combustion of fuel.
2. Blue Smoke: The blue smoke is usually due to excessive lubricating oil consumption and its emission indicates a very poor condition of the engine, such as worn out piston rings or valve guides, etc.

The factors affecting Diesel smoke are Fuel Factors, Engine Design, Effect of engine life and maintenance.

Fuel factors are Cetane Number, Volatility, Viscosity and Chemical Composition.
Considerable success has been achieved in recent years on diesel smoke problems by means of fuel additives; of which certain additives containing barium effectively reduce the exhaust smoke density.

Engine Design: The type of combustion system is the most important engine design features, which affects exhaust smoke density. An indirect injection engine releases less smoke than a direct injection engine for large part of the operating range of loads, due to high rate of air swirl resulting in better air utilization.

Effect of Engine life and maintenance: From the engine maintenance point of view, the condition of the fuel injection system has the greatest influence on exhaust smoke density. To perform the functions of engine satisfactorily throughout the engine service life, all the components of the fuel system must be in good mechanical condition and must be correctly assembled and tuned. As the wear of these components with increasing use is inevitable, and as deposit build up takes place on some of the critical components, periodic maintenance is essential to keep the smoke level low.

2) Mitigation Measures by the Use of Alternative Fuels

The vehicular pollution can be reduced by the use of alternative fuels, which is given as below.

1) LPG
2) CNG
3) Bio-Diesel Blends
4) Battery operated
5) Hydrogen
6) Solar operated

LPG: Liquefied Petroleum Gas is mixture of gases, chiefly propane and butane, produced commercially from petroleum and stored under pressure to be kept in a liquid state. The LPG is an attractive fuel for internal combustion engines; because it burns with little air pollution and little solid residue, besides that, it does not dilute lubricants, and it has a high octane rating.
The international research experience in this area indicates that there is 90% reduction in toxic emissions as compared to reformulated gasoline, in addition, it also reduces the CO2 22-24% as compared to gasoline. (Source: Book-Gupta R, "Automobile Engineering" Satya Prakashan, New Delhi, 2009, page No.979)

CNG: Compressed Natural Gas is composed of Methane, Ethane, Propane, Butane and other contaminants. The main constituent of CNG is Methane which will be up to minimum of 90%. Due to its low energy density, it is compressed to a pressure of 200-250 kg/cm2 and the name is Compressed Natural Gas.

TABLE: - COMPARATIVE EMISSIONS FROM DIESEL AND CNG FOR BUSES

Fuel	Pollution Parameter		
	CO	NOx	PM
Diesel	2.4 g/km	21 g/km	0.38 g/km
CNG	0.4 g/km	8.9 g/km	0.012 g/km
% Reduction	84	58	97

It reduces CO to 97%, HC to 20 to 25% as compared to gasoline fuel.

Bio-Diesel Blends: To cut foreign exchequer and contribute towards protection of earth from the threat of environmental degradation, bio-fuels can be good alternative for diesel for most of developing countries. Vegetable oils have considerable potential to be considered as appropriate alternative as they possess fuel properties similar to that of diesel. There are more than 300 different species of trees in India which produce oil bearings.

The following table shows the reduction in various pollutants by the use of Bio-Diesel blends.

TABLE: - AVERAGE BIO-DIESEL EMISSIONS COMPARED TO CONVENTIONAL DIESEL

Emission Type	B100	B20
Total Unburned Hydrocarbons	-67%	-20%
Carbon Monoxide	-48%	-12%
Particulate Matter	-47%	-12%
NOx	+10%	+2% t0 -2%

If B100 i.e.100% blend of Bio-Diesel is in use, then the Unburnt Hydrocarbons will be reduced to 67%, Carbon Monoxide to 48%, Particulate Matter to 47% and Nitrogen Oxide may be minimized by two percent or it may increase.
If B20 i.e.20% blend of Bio-Diesel is in utilization, then the Unburnt Hydrocarbons will be reduced to 20%, Carbon Monoxide to 12%, Particulate Matter to 12% and Nitrogen Oxide may increase by 10%. But here the Nitrogen oxide problem may be minimized by using the catalytic convertors.

Battery Operated Vehicles: The vehicles use the battery power to move the vehicle. The batteries are recharged by conventional trickle charging method or alternators to charge the same, where as yet inventions are in progress to charge the battery fully on alternators. Now in India REVA car is popular for battery operated vehicle, the Vidyut and some other motors have launched two wheelers. As of now, these vehicles run with 40 to 80 km/hour. By these battery powers, operated vehicles exhaust emissions will zero, as no fuel is burned to produce energy.

Hydrogen fueled vehicles: Hydrogen is high in energy content as it contains 120.7 MJ/kg, which is the highest for any known fuel. However, its energy content compared to volume is rather low. This poses challenges with regard to its storage for civilian applications, when compared to storage of liquid fossil fuels. When burnt, hydrogen produces water as a by-product and is, therefore, environmentally friendly. Although no CO2, etc. will be produced, if hydrogen is burnt in air, yet NOx will be formed at high temperatures. One of the advantages of hydrogen as a fuel is that it can be used directly in the existing internal combustion engines and turbines and can also be used as a fuel in fuel cells for electricity generation. Hydrogen applications, besides industrial application, cover power generation, transport applications and heat. However, when compared to other alternatives, use of hydrogen in transport sector appears to be more beneficial as it is possible to store hydrogen on-board.

Solar Operated Vehicles: Solar Photo Voltaic method is used with solar panels placed on the vehicles and designed as per the Aerodynamic necessities of vehicles. By using solar, the batteries can be recharged and with the battery power, the vehicles can operated where no tail pipe emissions will release. Yet more innovative efforts have to make to attract the people towards solar operated vehicles.

Conclusion

Air pollution is one of the serious environmental concerns of the urban Asian cities including India, where majority of the population is exposed to poor air quality. The health related problems such as respiratory diseases, risk of developing cancers and other serious ailments, etc. due to poor air quality are known and well documented. Besides the health effects, air pollution also contributes to tremendous economic losses, especially in the sense of financial resources that are required to give medical assistance to the affected people. The poor are often the most affected segment of the population as they can't access adequate measures to protect themselves from air pollution.

The pollution level can be minimized by the use of innovative and technical methods as well as the alternative fuels. If so, the health ailments caused by these pollutants can be reduced significantly.

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