AUTOMOBILE POLLUTION AND THE ENVIRONMENT

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It is widely recognised that air pollution caused by the global rapid increase of automobile traffic is a threat to the environment. With regard to automobiles there are three general areas of concern: urban pollution, especially in highly populated cities with high density of private transport, depletion of the ozone layer and pollution resulting in disturbance of natural environment. Several methods of effective control of automobile emissions to meet current and future environmental demands are analysed

1 INTRODUCTION

A widely used definition of pollution is the introduction by man into the environment of substances or energy liable to cause hazards to human health, harm to living resources and ecological systems, damage to structures or amenity, or interference with legitimate uses of the environment.

Considering all major anthropogenic source categories, with exception of agriculture, the transportation sector of our economy releases about one-third of the total emissions of VOCs (Volatile Organic Compounds), nitrogen oxides (NO_x), and lead (Pb) and more than two-thirds of the carbon monoxide (CO). The CO and the VOCs, (almost all as hydrocarbons) are products of inefficient combustion, which would be eliminated by burning the fuel to carbon dioxide (CO_2) and water (H_2O) in the engine of the vehicle to produce power if possible. Most of the VOC emissions are from the tailpipe. These are controlled using catalytic reactors and by injecting air at the exhaust ports of the engine to burn emitted hydrocarbons in this high-temperature zone. Neither process recovers useful energy, so efforts to modify engine design have been intense. However, more than 20% of the uncontrolled automobile engine VOC emissions are from the crankcase vent (blow-by and evaporating oil) and from the carburettor vent to the atmosphere. These emissions are controlled using a crankcase vent pipe to the engine intake duct (requiring a pollution control valve or PCV) and a 'carbon canister' absorption unit for evaporative losses. Fuel injection systems, with their advantage of providing much more precise metering of fuel to the cylinders, significantly reduces pollutant emissions, including further reduction of evaporative losses. Presently, use of oxygenated fuels is encouraged to reduce VOC emissions at the tail pipe [1].

Researchers have found that it was necessary to reduce emissions of nitrogen oxides to reduce photochemical smog and rain precursor emissions. One of the most effective ways to reduce these oxides is by introduction of exhaust gas recirculation (EGR), and by using two-stage combustion. High levels of lead emissions have been tackled by the introduction of lead-free gasoline, mandated in developed countries like USA but optional for developing countries like Botswana. Driving behavior and route driven (e.g. shifting gears and speedy accelerations) factors contribute to automobile pollution. Control of emissions depends on several factors such as driver's experience, type of route used, and in-use factors such as wear, maintenance, and malfunction conditions [1,2]. Automobile pollution can also be reduced, partially or completely (zero emission) by using lean-burn engines (i.e. engines that offer air/fuel ratios in the 22 – 23 : 1 range, as opposed to conventional engines which operate on stoichiometric ratio of 14.5:1), intelligent transport systems (ITS), automatic pilot systems or better routing of traffic to cut fuel consumption while at the same time reducing pollution and enhancing safety, or using other alternative types of vehicles such as hybrid or electric [3–5]. The worsening problems of atmospheric pollution from motor traffic in many of the world's cities have led to the increasing strigent emissions regulations.

In this work, formation of automobile pollutants and their effects and control are addressed.

2 MOTOR TRAFFIC POLLUTION

Transportation is the single sector that utilises most of the fossil fuels such as petrol, diesel, kerosene and methanol. Pollution is the most serious of all environmental problems and constitutes a major threat to the health and well-being of millions of people around the world and global ecosystems [6].

The dramatic increase in public awareness and concern about the state of the global and local environments which has occurred in recent decades has been accompanied and partly prompted by an ever growing body of evidence on the extent to which pollution has caused severe environmental degradation. The introduction of harmful substances into the environment has been shown to have many adverse effects on human health, agricultural productivity and natural ecosystems [7,8].

The full impact of the effects on the environment caused by the transportation sector can be evaluated

by external costs that the society has to pay for. Typical costs are forests damaged by acid rain or skin diseases caused by the ozone hole. The worsening problems of atmospheric pollution from motor traffic in many of the world's densely populated cities have led to the introduction of legislation to try and mitigate or prevent the nuisance.
This has included the phasing out of tetraethylleaded (Pb) additives in petrol (unleaded petrol), lean burn and the introduction of catalytic converters in many countries. However, air quality problems still pose serious problems in most large cities and there appears to be no way of preventing them completely unless private cars are banned from city centres and environmentally sound public transport systems are introduced. In Britain for instance, many people are encouraged to use public transport, and a penalty for use of private vehicles is to be introduced. In Switzerland and most Scandinavian countries more and more people are encouraged to use bicycles.

The fast depletion on a global scale and expected exhaustion of petroleum reserves in the middle of the 21st century may help to force the issue. The costs of these effects in the depreciation of resources, lost productivity and in cleaning up or improving polluted environments are high. Governments, non-governmental organisations and politicians around the world, especially in technologically advanced countries are paying special attention to these issues [6].

3 CURRENT STATUS ON ENGINE EMISSIONS

Since the 1950's it has been recognised that transportation engines in developed countries are the major source of air pollution. While it is apparent that the proportions to be attributed to various causes vary both in time and from place to place, typical USA figures are shown in Table 1. It can be seen that transportation is responsible for the biggest share of CO, HC and NO_x in the atmosphere as well as a large proportion of the particulate matter.

Table 1. Proportion of atmospheric pollutants from various sources [9]

Source	CO %	Sulphur Oxides %	Hydro-carbons %	Parti-culates %	NO_X %
Transport	92	4	65	14	42
Industry	4	32	26	44	21
Electricity generation	0	48	0	21	32
Space heating	3	12	3	14	5
Refuse burning	1	4	6	7	0

The particulates given in the table do not include dust from the road, rubber particles from the tyres, photochemical smog particles or asbestos from brake linings. They are merely the carbon particles that are directly attributable to the exhaust system.

4 FORMATION, EFFECTS AND CONTROL

4.1 Unburned Hydrocarbons (UHC).

Emissions of hydrocarbons indicate low combustion efficiency in internal combustion engines and they arise when vapourised unburnt fuel or partially burned fuel products, leave the combustion region and are emitted with the exhaust.
Unburnt hydrocarbon emissions are independent of air/fuel ratio. They can arise from shortcomings in the fuel injection system. Some of these might be readily overcome, whilst others are inherent in trying to operate an engine over a wide speed range.
Two of the features of the fuel injection systems that give rise to hydrocarbon emissions that can be overcome are secondary injections and high nozzle sac volumes. Secondary injections occur when wave effects in the fuel lines cause the nozzle to reopen and give a small injection of fuel after the main injection. Since the second injection of fuel occurs late in the expansion stroke, the fuel is not burnt completely and is emitted into the exhaust system when exhaust valve opens.
The sac of the fuel injector contains a volume of fuel. This fuel often evaporates out of the sac later on during the expansion stroke when the conditions are not favourable for complete combustion. A way of reducing hydrocarbon emission from this source is either to reduce the nozzle sac volume or if possible eliminate it completely.

Although the amounts of UHC are relatively small they are objectionable because of the odour, their influence in the formation of photochemical smog and possible carcinogenic effects. The odour is more noticeable with extremely lean mixtures typical of diesel and stratified charge engines.

4.2 Oxides of Nitrogen (NO_x).

Motor vehicles are the principal source of NO and of its oxidation product NO_2.
The formation of oxides of nitrogen is a highly temperature-dependent phenomenon and occurs because the equilibrium concentrations of the various NO_x compounds formed when oxygen and nitrogen are mixed are high at adiabatic flame temperatures of approximately 2000K to 3000K but low at ambient temperatures. The two mechanisms that explain the generation of nitrogen oxide emissions in the combustion chamber are the 'Zel'dovich' and the

'prompt' NO [6, 9]. In both cases the nitrogen oxides are generated by the reaction of nitrogen and oxygen from air. The Zel'dovich mechanism can be represented by the following chemical equation:

$$O + N_2 \Rightarrow NO + N \quad \text{.....................(i)}$$

$$N + O_2 \Rightarrow NO + O \quad \text{.....................(ii)}$$

with reaction (i) as the rate determining step.

The final emission also tends to be proportional for isothermal flames to post-temperature residence times. The 'prompt' mechanism involves the reaction of the hydrocarbon fragment with molecular nitrogen. This mechanism is only weakly temperature dependent and therefore accounts for only a relatively small portion of the emissions.

Oxides of nitrogen are important constituents of photochemical smog. In addition to the greenhouse effect, oxides of nitrogen contribute to environmental pollution in three ways: depletion of the ozone layer, production of acid rain and general air pollution.

A comparison of vehicle usage indicates where measures for control of NO_x are best directed (Table 2). A very high level of private vehicle usage is observed in Los Angeles, consistent with the present social threat this represents. The major European cities have a similar pattern of use. Summation of the last two columns gives a transport shortfall for each city which is accounted for by cyclists and pedestrians; this is still significant in Europe and in Amsterdam amounts to 28%. The record for Moscow shows that a major city can function with minimum use of private transport. Much can be done through economics of consumption of motor fuel and by suitably modifying existing engines. Other possible measures of control of NO emissions include:

1. Keeping the compression ratio below the usual 10:1. This has the effect of reducing the combustion temperature, which is unfavourable to the initial fixation reaction and hence reduces the yield of NO.
2. Enriching the air fuel mixture to bring the post-combustion level as low as possible, i.e. reducing combustion temperature.
3. Retarding ignition timing, though this leads to reduced performance and fuel economy.
4. Unburnt fuel and NO can be removed from the exhaust using a catalytic converter. The action takes place in two stages. In the first NO_x is reduced to N_2 using unburnt fuel and CO as reducing agents, and the second stage the remaining CO and fuel are oxidized by injection of air at 400°C.
5. Recirculating some exhaust gases. Exhaust Gas Recirculation (EGR) reduces the cycle temperature and therefore NO_x emission, though the limits of the extent of the EGR which can be applied is about 15%.

Table 2. Transport patterns in cities.

Cities	Petrol use 10^3 MJ per capita	Vehicles per 1000 Population	Proportion public Transport %	Proportion private Transport %
Los Angeles	58	670	7.5	88
New York	44	460	28	64
London	12	355	39	38
Munich	12	400	42	38
Paris	14	385	40	36
Amsterdam	9	340	14	58
Melbourne	29	530	21	74
Moscow	0.4	40	74	2

4.3 Carbon Monoxide (CO).

Most of the CO in the ambient air comes from vehicle exhaust. Internal combustion engines do not burn fuel completely to CO_2 and water; some unburned fuel will always be exhausted, with CO as a component. CO in vehicle exhaust can be reduced by using partially oxidized fuels like alcohol and by a variety of afterburner devices. CO tends to accumulate in areas of concentrated vehicle traffic, in parking garages, and under building overheads [2].

4.4 Carbon Dioxide.

The fuel consists of organic molecules which are mostly hydrocarbon. When such compounds are burnt in automobile engines they yield carbon dioxide and water. Carbon dioxide also contributes to the acidity of rainfall, but more important, CO_2 is transparent to short-wavelength radiation from the sun but opaque to longer wavelengths radiated back to space from the earth. Thus increased concentrations of CO_2 may result in a heating of the earth's atmosphere and global warming.

4.5 Photochemical Smog

The components of automobile exhaust are particularly important in the formation of atmospheric ozone, and are primary contributors to smog. Smog is a mixture of ozone, aldehydes, oxides of nitrogen and hydrocarbon. It results from reaction of these compounds in the atmosphere through a complex chain mechanism requiring photolysis due to the action of sunlight. The amount of smog depends on the concentration of reactants, their reactivity, the temperature and light intensity. Photochemical smog causes severe irritation of the eyes, throat and respiratory system. In addition to this, it causes damage to some materials and is therefore a major problem especially when it is held down in the local atmosphere of major cities by a temperature inversion, (Los Angeles as opposed to

London smog). Adequate control of ozone and photochemical smog production depends on control of all primary pollutants that contribute to ozone formation.
It is evident that major cities with a combined high vehicle per population and proportion of private transport will not only be affected by smog but pollution in general as shown in the transport patterns in some major populated cities, Table 2.

4.6 Lead Emissions.

Vehicle exhaust is one of the sources of lead pollution in the environment. The combustion of gasoline containing lead (Pb) additives gives rise to large amounts of lead particulates which are deposited downwind of highways. High lead levels from automobile exhaust are controlled by elimination or phasing out of lead from gasoline i.e. by using unleaded gasoline.

5 DRIVING MODE

Vehicle emissions are also heavily dependent on the way the engine is being operated, as shown in Table 3. During acceleration, the combustion is efficient, hydrocarbon (HC) and carbon monoxide (CO) emissions are low, and a high compression produces a lot of oxides of nitrogen NO_x. On the other hand, deceleration results in low variation NO_x and high HC and CO because of the presence of unburned fuel in the exhaust.

Table 3. Typical Vehicle emissions from uncontrolled spark ignition 300 – CID, four stroke engine (equipped with a carburettor) [10].

MODE (Operation)		EXHAUST EMISSIONS		
		NO (ppm)	HC (ppm)	CO (ppm)
Idle		30	350	17000
Cruise:	City	1000	200-400	6000
	Highway	1000	200-400	5000
Acceleration:	Part throttle	1700-2500	350-400	7000
	Maximum	700-1200	350-400	
Deceleration:	Free	60	1200	
	Braking	60	1200	18000

6 DISTURBANCE OF NATURAL ENVIRONMENT

The problems of growth associated with demand for energy and supply by combustion of fossil fuel have already been stressed.
Continued depletion of the ozone layer, due to emissions, has serious consequences for the earth's ecology since it leads directly to an increased exposure to light in the 200 – 300 nm range. This kind of radiation is toxic to unicellular organisms and to the surface cells of animals and higher plants [2].

6.1 Effects of Greenhouse Warming.

A fundamental uncertainty is the past effect of variations in the emissions from the sun, the brightness of which varies by up to 0.1% in phase with magnetic activity. Over a century (temperatures recorded in 1860) the earth's temperature has risen by 1°C, the month of July 1990 being recorded as the hottest [11]. The consequences of greenhouse warming in 1998 could be summarised as follows:

(a) Over six hundred deaths were reported in some states of USA as heat waves swept across such states like Texas.
(b) There have been reports of melting ice in the Arctic. This could have a direct threat to communities on low-lying islands sooner or later.
(c) Countries like Greece and elsewhere experienced fires.

6.2 Effects on Agriculture

The changes referred to in 6.1(a) will lead to a progressive shift in the meteorological equator, although this change may be delayed. It is forecasted that the following scenario will take place [2, 12].

- The African desert would move northward and some areas of Spain, Italy and Greece would may become deserts.
- With reduction of rain fall, California may resemble Mexican desert and a similar change would also be expected in Punjab of India.
- The South East of the United Kingdom will become drier and the growth of arable crops would tend towards the west.

6.3 Desirable measures

Some of the measures to contain the above effects would include:

- Energy conservation
- Stricter control of vehicle emissions.
- More efficient use of fuels through speed limitation.
- Greater use of public transport.
- Use of hybrid or electric vehicles particularly in densely populated cities.
- Effective use of latest technology such as fuel management systems and intelligent transport systems that interact drivers, vehicles, and the infrastructure with high-tech information and telecommunications technology.
- Use of alternative sources of energy such as solar and fuel cells.

7 VEHICLE EMISSION STANDARDS

Vehicle exhaust emission (CO,HC,NO_X) legislation has been passed in many countries. Some countries have their own regulations but generally existing test procedures and standard have been adopted as a rule. An overview of the Plan which is to reduce emission standards in three stages and which lays down the emission standards to be observed for newly registered cars with Otto and Diesel engines is well documented by Mercedes-Benz and Schadstoffiniderung bei Kraftfarhrzeugen [13,14].

8 CONCLUSIONS

It is evident from the current work that pollution from combustion of petroleum – based fuels in automobiles account for a major part of atmospheric pollution. It has been stressed that pollution has serious effects on the health and well-being of human beings and environmental degradation.

Future solutions lies, as far as the emissions of carbon monoxide, hydrocarbons, nitrogen oxides and particulates are concerned, in rigorous pollution regulations and use of other alternative forms of energy.

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