EMISSIONS FROM HEAVY DUTY VEHICLES: HEALTH AND ENVIRONMENTAL IMPLICATIONS AND LEGISLATIVE REMEDIES

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ABSTRACT

This paper will deal with an aspect of the heavy-duty transport field that is, at least in South Africa, almost totally neglected; the issue of exhaust emissions, both gaseous components and particulate matter. It will examine the source, nature and toxicity of these emissions, and the implications of the current lack of regulation in South Africa.

The paper will examine methods of after-treatment, and will briefly cover exhaust gas recirculation, catalytic converters, de-NOx catalysts, diesel particulate filters and particulate traps. The effect of legislation on engine and exhaust gas treatment systems will be explained, as will past, current and future legislative strategies from the developed world.

A correlation will be made between increasingly stringent emissions laws and the consequent improvements in ambient air quality in both the USA and continental Europe, and this will be related to the situation in the major metropolitan areas in South Africa.

The implications of high-technology exhaust treatment systems on fuel quality will be briefly covered, and again the international and local situations will be compared.

Finally, the paper will look at current activities in the HD transportation world, derived from the author's experience with UN ECE WP.29 GRPE, the international working group on pollution and energy. It will cover the upcoming WHDC program, the extension of legislation to non-road mobile machinery, and the advent of on-board diagnosis – including its possible use as a regulatory tool.

Keywords: diesel, emissions, fuels, legislation, environment

THE PROBLEM

Introduction

Although it is the subject of considerable international debate and resource expenditure, one aspect of the heavy-duty transport field that is almost totally neglected in South Africa is the issue of exhaust emissions, both gaseous components and particulate matter. This document examines the source, nature and toxicity of these emissions, and the implications of the current lack of local regulation on human health and the environment.

The health effects of the most critical gaseous components, and also the effects of particulates, are discussed in broad terms, to justify the necessity for progress in limiting such emissions by national laws. The longer-term effects on ambient air quality and the environment are also covered, highlighting the inter-dependency of all nations in maintaining a sustainable planet.

Gaseous emissions - source, nature and toxicity (from both petrol and diesel engines)

A motor vehicle uses a fossil fuel, be it petrol or diesel, to produce energy by burning that fuel in the presence of air. The energy released is converted into work by the reciprocating and revolving parts of the engine and the by-products of combustion are released into the atmosphere. This is a simple description of that process, it will not cover the multiplicity of chemical reactions that take place, and is aimed only to give a broad overview of the health and environmental problems posed by motor vehicles.

Petrol and diesel fuels are a blend of hydrocarbons, but for the sake of this paper all the constituents are taken together to have a chemical formula of C_nH_m. This burns in the presence of air, which is comprised of 78.1% nitrogen and 20.9% oxygen. Obviously oxygen is required for the combustion process, and if only that component was involved the exhaust emissions would be far less problematic. Unfortunately, nitrogen also takes part in the process, and yields undesirable by-products. Fuels also contain varying amounts of sulphur, which further complicates combustion by-products.

In an ideal world, the hydrocarbons would combine with adequate oxygen and would simply burn to form carbon dioxide and water.

In chemical terms; $C_nH_m + O_2 \rightarrow CO_2$ and H_2O (carbon dioxide and water)

In real life, because of mixture variations in the engine, high temperatures during combustion, engine wear, and because of the presence of both nitrogen in the air burned and sulphur in the fuel, the exhaust gases are not so innocuous.

Thus we have;

$C_nH_m + O_2 + N_2 + S \rightarrow$ CO_2 and H_2O

NO and NO_2 (oxides of nitrogen - lumped together as NOx)

C_nH_m (unburned hydrocarbons)

CO (carbon monoxide)

SO_2 (sulphur dioxide)

Of these, the most toxic are CO and NO_2, both of which can cause severe tissue damage or even death to humans. Petrol engines emit more CO than diesels, primarily because of imperfect fuel distribution at part throttle leading to mixture variation across the combustion chamber. Diesel engines emit more NOx, because of their lean-mixture operation and consequent higher combustion temperatures. As diesel engines are the subject of this paper, petrol emissions are only covered very briefly.

Carbon monoxide

Carbon monoxide displaces oxygen and binds more readily to the haemoglobin in red blood cells, causing death by suffocation. To illustrate its toxicity the EPA (see Glossary) issue advisory bulletins if the ambient CO levels rise above 9ppm (see Glossary) and advises the evacuation of buildings at 200ppm, at which concentration headaches would be experienced after several hours exposure. Compare these levels with vehicle emissions; idling petrol engines are the worst offenders, an older generation car could emit 10,000 to 15,000ppm CO (which would be fatal in less than 30 minutes) so it is not surprising that the EPA have found that up to 95% of ambient CO in city areas comes from stop-go traffic (EPA, 2003).

Nitrogen dioxide

NO_2 combines with water to form nitric acid, so it will react with the water present in human eyes, upper respiratory tissues and lungs, to cause either irritation or damage. The EPA limit for NO_2 is 0.053ppm, between 10 and 13ppm will cause eye irritation, burning nose and throat and cough, while exposure to 100ppm could result in death from lung damage.

The relationship between toxic effects and typical heavy vehicle emission values are shown in Figure 1 below; a "High-Tech diesel" typically has a common-rail system, with electronic engine management and a 2-way oxidising converter. Note that even these vehicles emit levels of NOx that can inhibit lung function, and therefore children and adults with cardio-pulmonary difficulties are particularly susceptible (EPA, 2003).

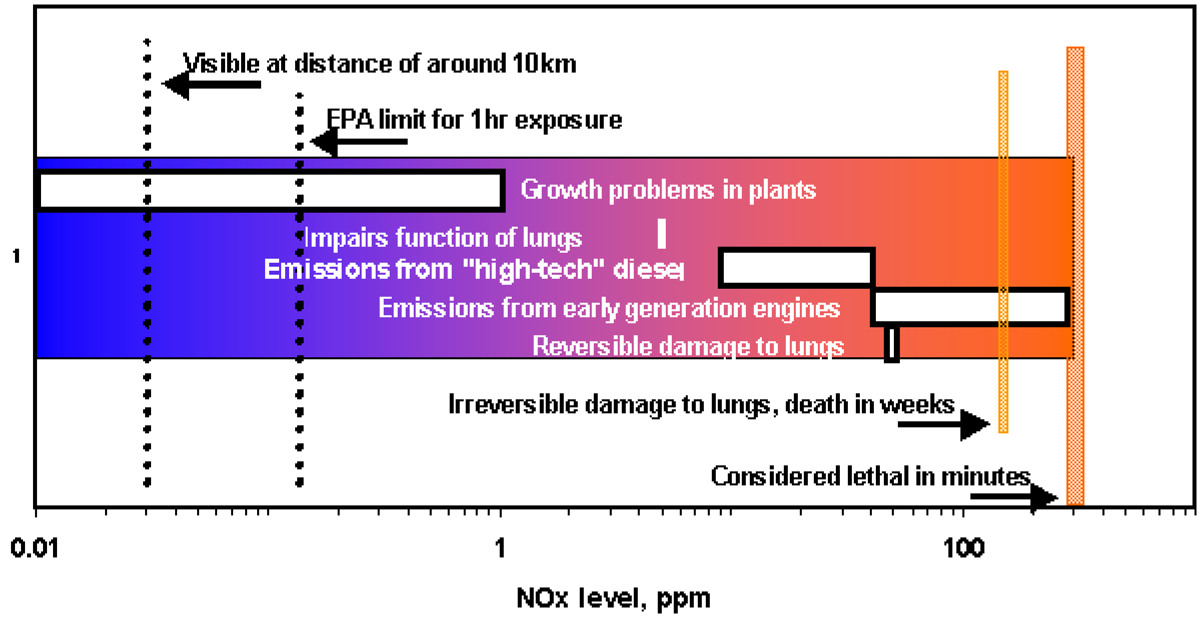

Figure 1. NOx level data.

The older-generation mechanical fuel injection systems result in NOx levels that could be highly dangerous, but it must be remembered that NOx formation occurs under substantial engine loads, which reduces the risk of long-term exposure. Operation of engines in restricted areas, such as mines and warehouses, needs careful monitoring and adequate ventilation, for obvious reasons.

Sulphur dioxide

SO_2 also combines with water; both within the engine, where it compromises oil additives and can damage components, and in the atmosphere, where it forms acid rain. In some instances the odour can be objectionable, this is particularly true of petrol vehicles equipped with a catalytic converter.

Particulate emissions - source, nature and health effects (primarily from diesel engines)

As well as the problem of gaseous emissions referred to above, diesel engines also emit particulate matter - mostly carbon particles - which vary in size down to microns. Particulates are generally classified by size; fine particles down to 2,5 microns, designated $PM_{2,5}$, are primarily products of combustion. Coarser particles, around 10 microns, are designated PM_{10}, and are primarily made up of dust from the road surface; less commonly they are the products of poorer combustion.

The size of the particles is related to combustion efficiency; which means that the new generation of energy-efficient engines emit smaller particles; and it is this small particulate matter that medical studies have shown to have a potential carcinogenic effect on humans. Particles below 10 microns can find their way into the lungs, and finer particles can penetrate further into these delicate tissues (EPA, 2003).

Particulate emission is visible as smoke; the heavier the smoke, the greater the volume of particles emitted and, usually, the greater the average particle size. Excessive smoke emission from diesel engines is normally a result of poor maintenance (insufficiently atomised fuel leading to incomplete combustion) or deliberate tampering to achieve more power by over-fuelling. The photograph below, taken in the Johannesburg area, is unfortunately not an isolated incident- probably because of the lack of legal repercussions for offenders.

Photograph 1. All too common traffic scene in South Africa.

Environmental issues

Apart from the obvious and immediate dangers from the toxic gases mentioned above, there are also longer-term implications of vehicle emissions that affect everyone on the planet. One of the products of combustion of any fossil fuel is carbon dioxide (CO_2) and, ironically, vehicles fitted with catalytic converters are worse offenders, because the cat converts the immediately toxic CO into CO_2.

CO_2 is one of the six recognised "Greenhouse Gases", which together are responsible for retaining more of the sun's heat in the lowest level of the earth's atmosphere – the troposphere – and hence contributing to the phenomenon of climatic change, also referred to as global warming. The Statistical Office of the European Communities (2003) had this to say "…climate change, one of the greatest environmental and economic threats facing the planet and a top policy priority for Environment Commissioner Margot Wallström. The Earth's average surface temperature rose by around 0.6°C during the 20th century and evidence is getting stronger that most of the global warming over the last 50 years is attributable to human activities, such as burning fossil fuels and deforestation, which cause emissions of carbon dioxide (CO_2) and other 'greenhouse' gases.

The EU wants all industrialised countries to take urgent action to reduce or limit their future greenhouse gas emissions in view of the consensus projection by the Intergovernmental Panel on Climate Change that global average surface temperatures will rise by 1.4-5.8°C by the end of this century if 'business as usual' continues. This temperature increase could trigger serious consequences for humanity and other life forms alike, including a rise in sea levels of an estimated 9-88 cm over the period that could flood coastal areas and small islands, and greater frequency and severity of extreme weather events" (EUROSTAT, 2003).

The retention of heat in the troposphere also results in a lowering of temperature in the next layer, the stratosphere, and this reduction in temperature inhibits the production of ozone. Ozone, only present in concentrations of around 10ppm, is the only atmospheric chemical that filters out the frequencies of UV (ultra-violet) radiation from the sun that are extremely damaging to most life forms on earth.

Thus the problem of global warming affects every person around the world, and regardless of an individual country's position on emissions, it is influenced by all the other nations. A coordinated and dedicated effort is needed to reduce CO_2 emissions, which was the rationale behind the Kyoto Protocol. It is unfortunate that America, which is responsible for about one quarter of global CO_2 production, has now refused to ratify the Kyoto treaty.

Europe, which also contributes around 25% of total CO_2 output, has ratified the treaty, but is struggling to comply with its provisions. Although the EU was on target for 2001, and achieved the 2% reduction (compared to 1990 levels) in CO_2 emissions, it is unlikely to meet the 8% reduction required by 2008-2012. According to a press release: "The European Union and many of its Member States will fail to meet their Kyoto Protocol targets for limiting greenhouse gas emissions on the basis of the domestic policies and measures implemented or planned so far, according to new projections compiled by the European Environment Agency. The main reason is a runaway increase in emissions from transport, especially road transport". (EEA, 2003)

To enable member countries to comply, the most probable government initiatives will involve taxation benefits for vehicles that emit lower levels of CO_2; i.e., those with smaller or more fuel-efficient engines, or perhaps those using hydrogen as a fuel source.

Current situation in South Africa

At this time, there is no legislation in place to limit the gaseous emissions from road vehicles – which is particularly ironic when one considers that 25% of the world's production of catalytic converters occurs in this country, and nearly half of the cars on our roads already have the devices fitted. Limits for M1 and N1 vehicles (see Glossary) were gazetted in August last year, to the outdated Euro 1 standard (see Glossary), and this becomes effective in February 2005 (when Europe adopts Euro 4!).

Heavy vehicles are currently covered by the Atmospheric Pollution Act (Government Gazette 1974), which only considers smoke emissions under free-acceleration conditions, and the Act is only applicable to naturally aspirated diesels. There is, as yet, no indication when gaseous emissions from HDD (see Glossary) vehicles will be regulated.

The effects of this lack of legislation are visible in a number of the major metropolitan areas; smog is visible most of the time in the Gauteng region and even the coastal cities (which normally have the cleansing effects of wind to mitigate the situation) are affected. Last June, Cape Town suffered a repeat of the "Brown Haze" problem that first occurred about four years previously. Unusually high temperatures and a total lack of wind resulted in a temperature inversion effect more typical of Los Angeles in the 1970's, with consequent smog formation.

In response to this, the Western Cape Provincial Government issued a by-law that extended the provisions of the Atmospheric Pollution Act to all diesel vehicles, and empowered the Traffic Department to act against offenders. This is expected to extend to other provinces in the future, as attention is at last being given to air quality issues (Province of Western Cape, 2003).

THE SOLUTIONS

Petrol vehicles

The emissions from modern petrol engines can be substantially reduced by the 3-way catalytic converter (cat), and a cut away section of a typical cat is shown in Figure 2. The gas reactions in the cat are noted in the figure, and will not be covered in any detail here.

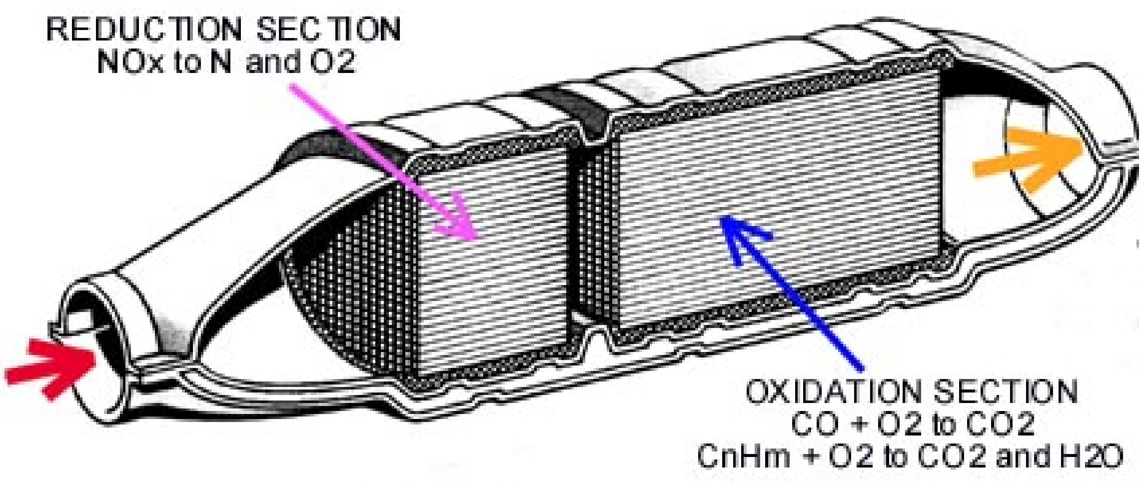

Figure 2. Typical 3-way Catalytic Converter (Cat).

Diesel engines

Gaseous components

In the last two decades, the design of diesel engines has progressed rapidly; most significantly in the areas of fuel injection systems, electronic controls, variable-geometry turbochargers and exhaust after-treatment devices. Although fuel efficiency is a critical factor in the heavy-duty market, much of the above development has been in response to stricter emissions legislation.

Many of the latest generation engines have common-rail or unit-injector designs; a common feature of which is far higher injection pressure than the old mechanical systems, coupled with precise electronic control of injection timing. Injection takes place in two, or sometimes even three, distinct pulses, enabling the reduction of combustion noise, the optimisation of power output and the lowest possible fuel consumption and emissions.

As has been mentioned in Chapter 1, NOx formation is largely temperature dependent, and initial efforts to control NOx concentrated on reducing combustion temperature. This was achieved by routing some of the exhaust gas back into the intake system (known as exhaust gas recirculation, or EGR), thus reducing the oxygen level of the fresh charge. To avoid compromising power output, this could only be done at part-throttle conditions, which obviously limits the effectiveness of EGR as an overall NOx reducer.

To comply with early legislation, diesel vehicles were also fitted with catalytic converters but, because a diesel normally runs with excess oxygen, the reduction section of a conventional 3-way unit would not function; so these units were 2-way oxidising types only. These converters controlled THC and CO emissions, but did not reduce NOx levels at all.

When the focus of heavy-duty diesel legislation was switched to NOx reduction, extensive research had to be conducted on the so-called de-NOx catalysts. These devices are also known as Selective Catalytic Reduction (SCR) systems, and use aqueous urea to yield ammonia, which reacts with the NOx molecules to form N_2 and H_2O. Because diesel exhaust is around 90% NO, some manufacturers also use a preliminary oxidation unit to generate adequate volumes of NO_2, see the schematic in Figure 3 on the next page. (Madia, G. 2002)

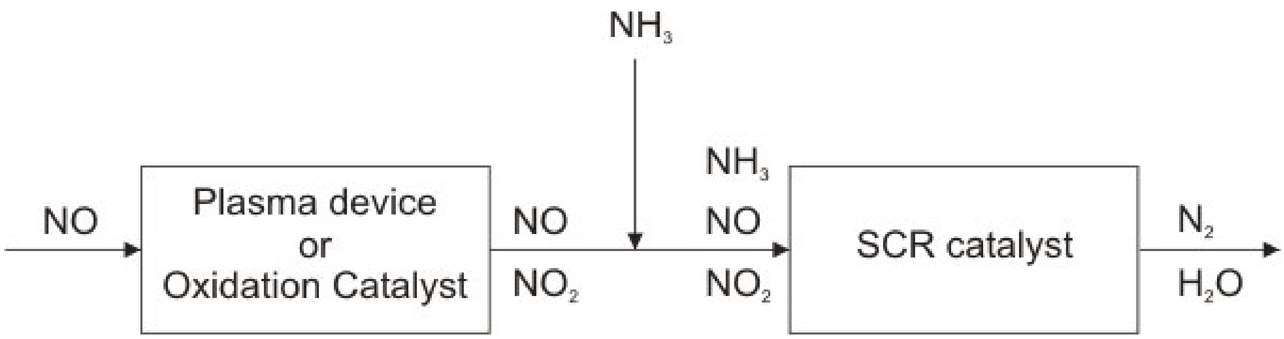

Figure 3. Schematic of combined oxidation catalyst and SCR (de-Nox Catalyst).

Particulates

To cope with the particulate problem, modern diesel vehicles are being fitted with particulate filters, otherwise known as DPFs. To ensure long-term compliance with legislation, and to reduce the maintenance burden, these units are now being designed to be regenerative – that is, they periodically clean the particulate deposits by introducing them back into the combustion system.

With the advances made so far, the target of zero PM emissions by 2007 is attainable, making diesel the prime choice for minimal environmental impact for conventional fossil-fuelled vehicles (EPA, 2003).

LEGISLATION

Introduction

Although some emission benefits occur as a spin-off from the manufacturers' drive towards ever- greater fuel efficiency, much of the development in this field is driven by the legislative requirements of the various countries. Two of the leading continents in this regard are the European Union and the United States of America, and this section looks at the Regulatory requirements of these two.

The increasing stringency of these regulations is demonstrated to have a beneficial effect on air quality, even though road traffic is only one of the emitters of the gases under study, and it can be seen that an overall pollution control strategy is needed (and, in these two cases, are already in place) to achieve positive results.

Manufacturers, end-users and consumers generally complain about the cost impacts of the new technology required to meet emission limits, and there is indeed an on-cost to the vehicle as amortisation of the development costs. Looking further, tighter limits often dictate an improvement in fuel quality, which in turn requires a new or better refinery process, and the fuel cost increases. But there is an up-side to this, seen in the improved health of a large number of people, and the EPA in America have put a value to this benefit that is far greater that the investment.

Regulatory requirements in the European Union (EU)

The European regulations for new heavy-duty diesel engines are commonly referred to as Euro I to EuroV. The Euro I standards for medium and heavy-duty engines were introduced in 1992 and the Euro II regulations into effect in 1996. (Note that this information refers only to HDD vehicles, legislation for petrol cars - ECR-R15/04 - was introduced in 1982).

In 1999, the European Parliament and the Council of Environment Ministers adopted the final Euro III standard and also adopted Euro IV and V standards for the year 2005/2008.

It is expected that the emission limit values set for 2005 and 2008 will require all new diesel-powered heavy duty vehicles to be fitted with exhaust gas after-treatment devices, such as particulate traps and De-NOx catalysts (Dieselnet, 2003).

The Euro limits described above are depicted graphically in Figure 5.

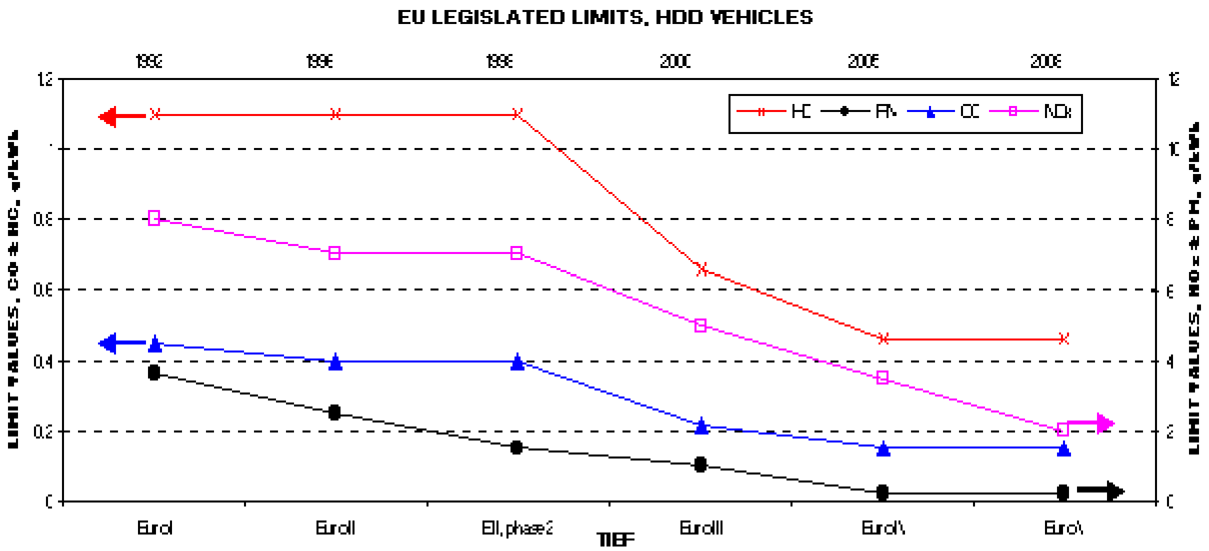

Figure 5. Legislated limits for Euro I to Euro V.

Note that Euro I and Euro II engines were tested to ECE-R49, which is a steady-state test, while for Euro III and IV three cycles are used. For ease of comparison, only the European Stationary Cycle (ESC) limits are plotted against ECE-R49, the transient and load response cycles are omitted.

The data presented in Figure 6, on the following page, shows the effect of legislation on ambient air quality, but it has to be borne in mind that the values are for all road traffic, so the correlation with HDD limits cannot be direct. Also to be considered is the significant increase in traffic volume that has occurred over the last three decades (185% growth in car population), and the 40% increase in tonnes kilometres of goods moved by heavy vehicles since the easing of trans-Europe travel resulting from the unification of the two Germanys.

Note that the data does not include emissions from industry or power stations, in fact road vehicles contribute only about 5% of the total pollutants, but it is reassuring to know that legislation is also pulling industrial emissions down – levels in 2000 are roughly 50% of the 1980 values. (Strelow, H. 2001) (Verstreng, V. Klein, H. 2002).

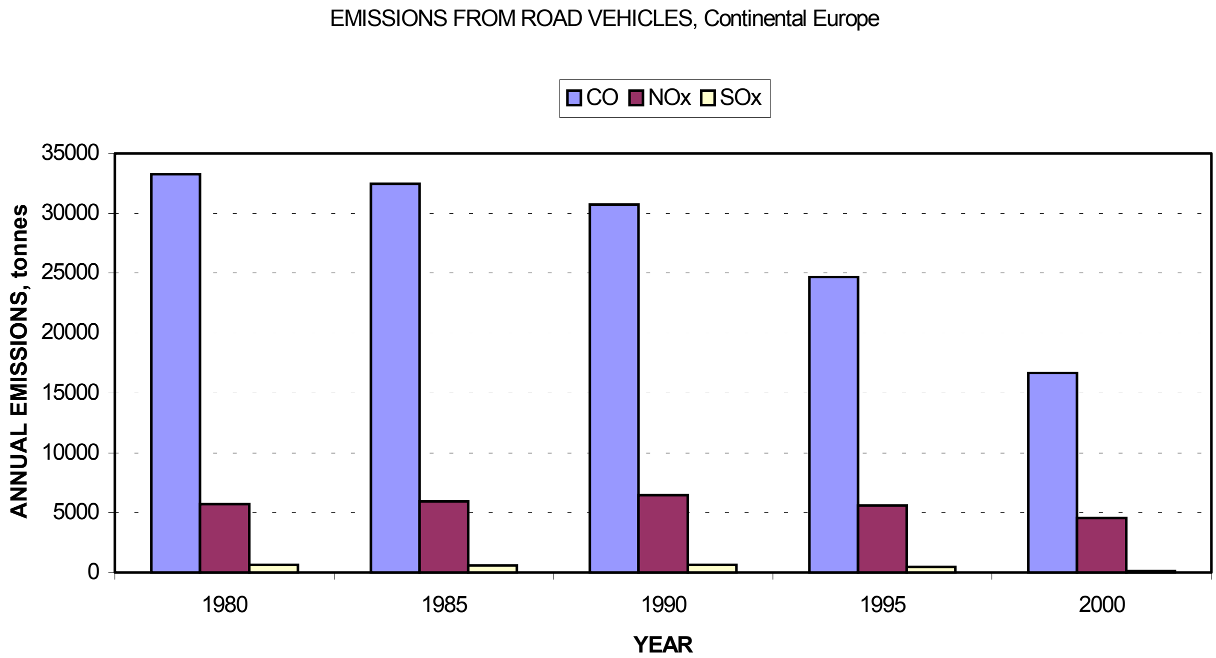

Figure 6. Road vehicle emissions, Europe.

As the corresponding emission limits for light duty vehicles were also becoming more stringent, the reduction of CO is expected. The almost static nature of the NOx emissions is logical; because, when looking at Figure 5, it can be seen that the limits were only reduced sharply in 1998 and, in the interim, increased vehicle usage compensated for reduced NOx output. The slow reduction in ambient NOx is the driver for the far tighter Euro IV and V limits, which in turn has pushed SCR research and development.

The American situation

Because of the situation in Los Angeles, the USA was considerably ahead of Europe, and California was already requiring minimal emission controls in 1964. Congress passed the first national Clean Air Act in 1970, and the EPA was formed in the same year. Unleaded petrol and catalytic converters appeared in 1975, and the 3-way type was introduced in 1981 (EPA, OMS 1994).

The legislators turned their attention to heavy-duty highway engines in 1990, and the limits have been steadily reduced since then. Currently the EPA and Congress are considering American policy for the next decade – the so-called 2007 legislation – and these values are included in the following chart. Note that the data is in g/bhp-hr, and thus cannot be directly compared with European limits (EPA 2003).

Figure 7 is a graphical representation of the EPA limits for all of the USA, except California.

(To avoid undue complexity only those states regulated by the EPA are considered in this paper: California, which has its own regulatory body – the Air Resources Board, or CARB – is not mentioned, as the limits are tighter than those of the EPA. Also omitted are any references to Corporate Average emissions or fuel consumption, or emissions trading, which would further complicate the issue).

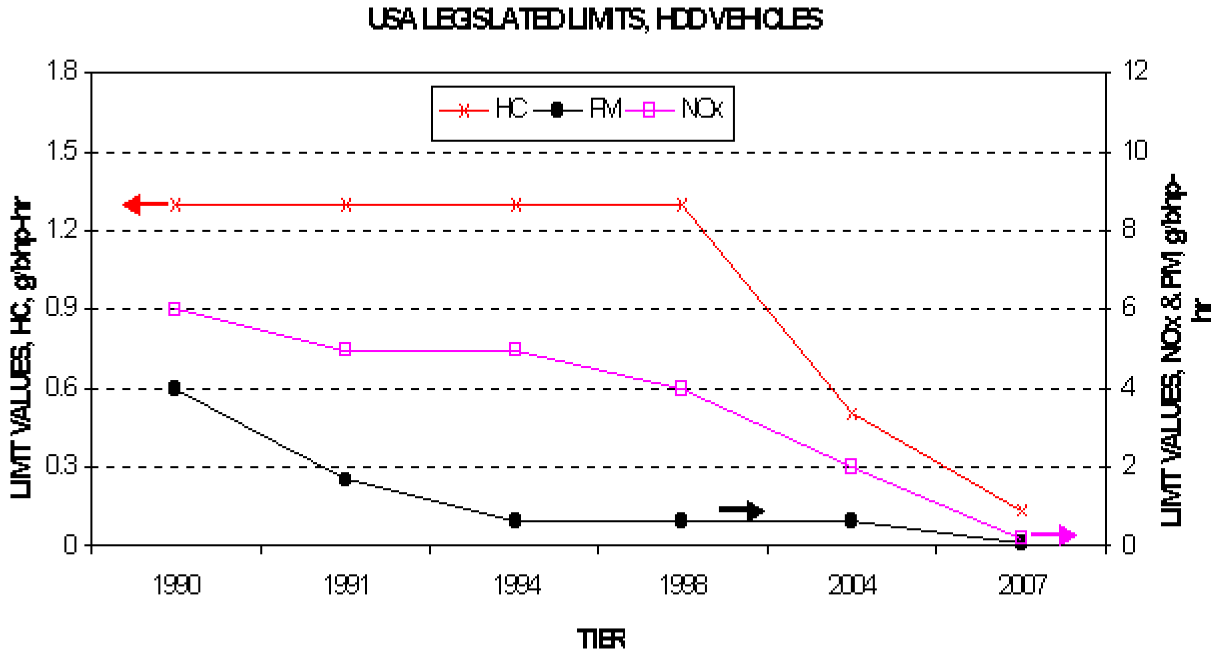

Figure 7. EPA legislative limits.

Comparison of the EU and American legislation shows very similar patterns, which is to be expected because, although legislation may attempt to drive technology, if a reduction is not technically feasible then compromises have to be made, and the application of that technology is then global.

Figure 8 shows the effect of the reduction in the legislative limits of three gaseous components on vehicle emissions, and compares actual figures with emissions that would have been experienced had the market remained unregulated. The latter data is calculated from known emission characteristics of non-controlled vehicles, and the cumulative vehicle mileages for the applicable year.

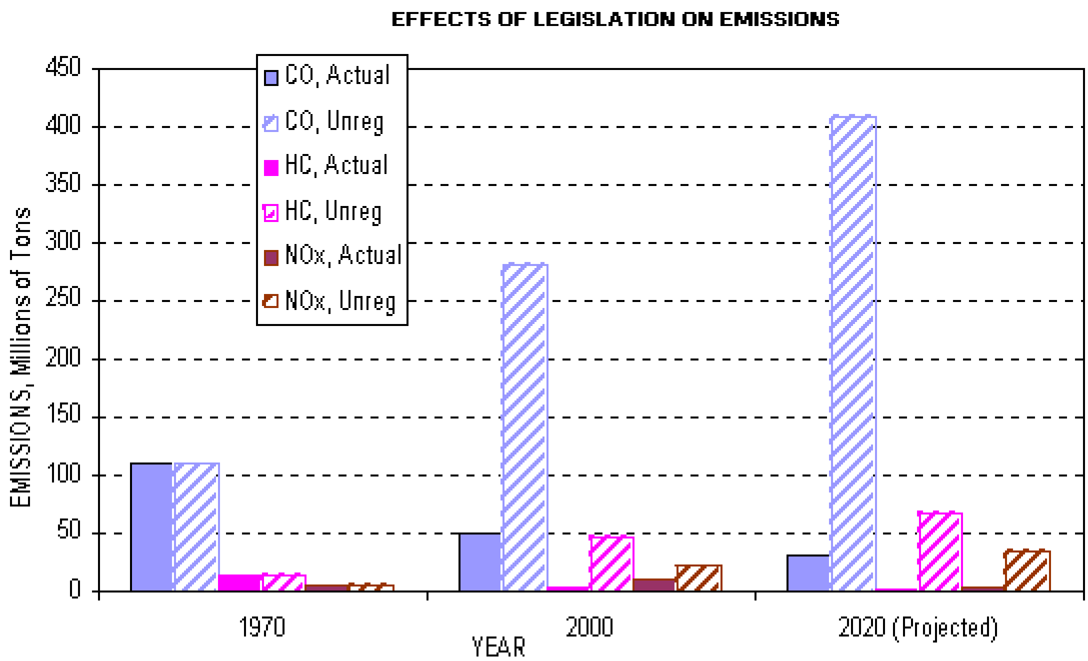

Figure 8. Road vehicle emissions, USA.

As can be seen, CO emissions in America have halved since 1970 and will halve again over the next 20 years, despite the expected 25% increase in passenger vehicle mileage and the projected 50% increase in tons-miles of goods transported by road. Hydrocarbon emissions follow the same pattern. NOx emissions increased to 2000, because of the lack of suitable after-treatment; with the advent of de-NOx catalysts, a significant reduction is anticipated for 2020. (EPA, 2003)

Fuel quality

As has already been stated, the application of some emission treatment technology involves some enabling factors. In the case of petrol vehicles, the most significant factor was the availability of unleaded fuel, which enabled the use of catalytic converters.

In the case of diesel engines, the most significant factor is undoubtedly sulphur levels. Sulphur is present to a greater or lesser extent in all crude oils, and has to be removed as part of the refinery process. Its presence has been tolerated until recently, because it generally improves the lubricity of diesel – important to prevent damage to high-pressure pumps and injectors – but alternatives are already in use.

As has been said in Chapter 1, sulphur combines with oxygen to form sulphur dioxide, this then further combines with water to form sulphuric acid. In the atmosphere, this falls as acid rain; in an engine the acid attacks the additives in the oil, reducing the total base number until the engine is unprotected. There can then be corrosion damage to metal components, especially those close to the combustion chamber, and this significantly reduces engine life.

If a diesel engine is fitted with exhaust after-treatment devices, sulphur is known to reduce the effectiveness of de-NOx catalysts, to increase the emissions of particulate matter and to permanently poison NOx adsorbers. As both NOx and PM emissions are now under the legislative spotlight, it is clear that reduction of diesel sulphur levels is a priority.

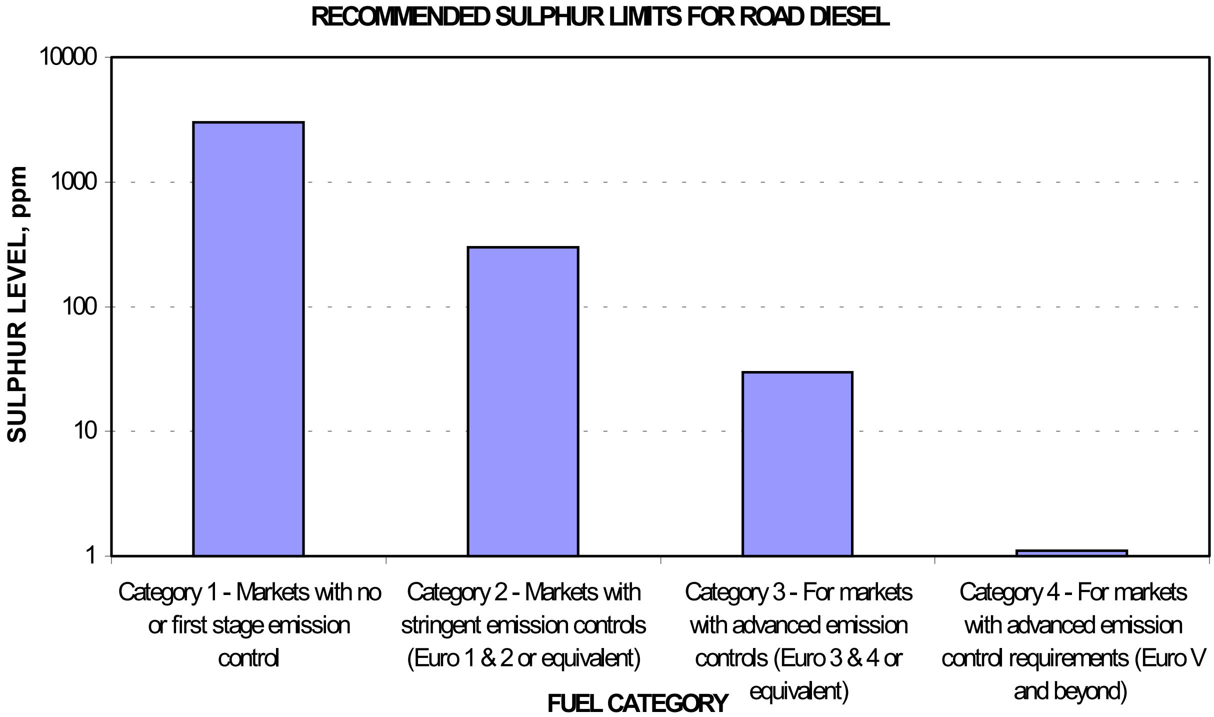

Figure 9. Manufacturer's recommended maximum sulphur level.

As can be seen from Figure 9, the contributing members of the World-Wide Fuel Charter (made up of the automobile associations of Europe, America and Japan) recommend maximum levels of sulphur in line with applicable emission limits. Exceeding these recommended limits will inhibit the application of known technology to control emissions.

These recommendations can be compared with the legislated limits, shown in Figure 10, as set by the governments of Europe and America over the last decade. For interest, the past, current and proposed South African limits are also shown; and, as with emission legislation, it is clear we are lagging behind the developed world. Note that the "Low-Sulphur" diesel is not yet available countrywide. (Mercedes-Benz 2003).

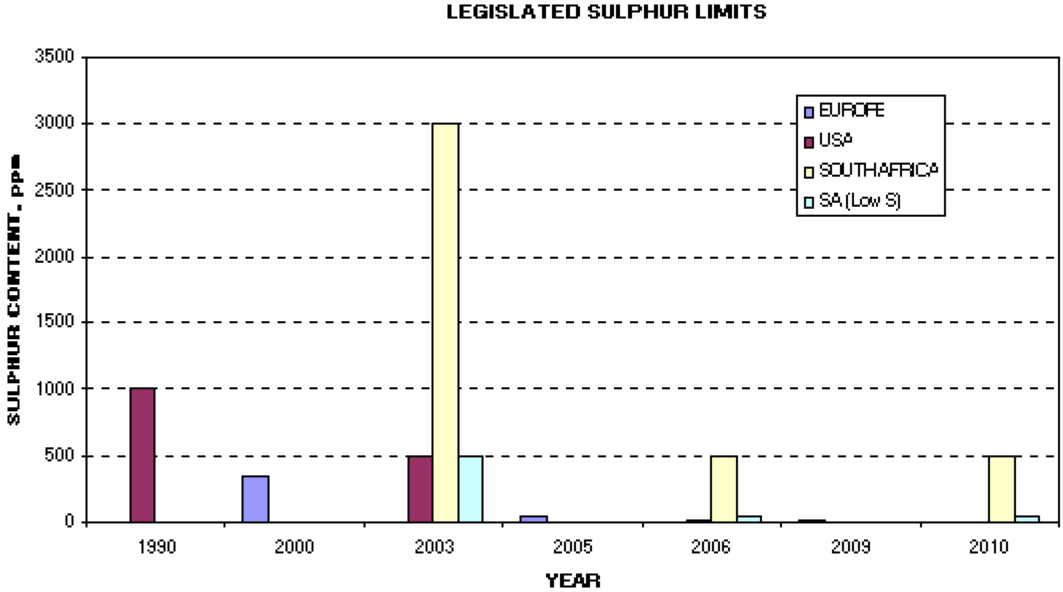

Figure 10. Legislated sulphur limits, EU, USA and RSA.

Cost and benefits

It is generally thought that compliance with ever-stricter emission legislation only involves expenditure. The automotive industry has to invest in research and development activities, and the production facilities needed to bring new technology to the market place, and they recoup this investment by increasing the cost of each vehicle sold. The refineries have to invest in new technology to achieve the required fuel quality, and they pass this on to the consumer as higher pump prices.

What is seldom considered is the monetary value of people's improved health as a direct result of better air quality. A study conducted by the EPA has indicated that the reduction in atmospheric pollution from mobile sources, as described in this section, together with substantial reductions in the emissions from power stations and industrial sources would yield the following: -

Industry and Power Stations
Cost of implementation = \$6,3 billion/yr
Health benefits (per year)
14,000 fewer deaths
30,000 fewer hospital visits
23,000 fewer non-fatal heart attacks
1,6 million fewer lost working days
200,000 less lost school days
By 2020, savings would be \$110 billion/yr

Mobile Sources
Development costs = \$600 million
High quality fuel costs = \$2,2 billion/yr
Savings of \$400 million/yr on vehicle maintenance
Similar health benefits to industry
By 2030; savings would be \$70,4 billion/yr

INTERNATIONAL STRATEGY AND THE WAY FORWARD FOR SA

With the growing trend to globalisation, where more and more manufacturers are building so-called "world cars" or "world trucks", there is a corresponding demand for commonised legislation. The key organization in this effort is the United Nations, Economic Commission for Europe (UN ECE), working through the World Forum for Harmonisation of Vehicle Regulations, otherwise known as WP.29.

WP.29 administers two principal Agreements; the 1958 Agreement, which provides procedures for establishing uniform prescriptions for motor vehicles and associated equipment, and reciprocal recognition of approvals issued under the Regulations annexed to the Agreement (currently there are 114 Regulations, covering all forms of motor transport); and the 1998 Agreement, which establishes a process whereby all participating countries can jointly develop global technical regulations regarding the safety, environmental protection systems, energy sources and anti-theft systems of all wheeled vehicles, equipment and parts.

South Africa became a Party to both 1958 and 1998 Agreements on 17 June 2001, which meant that from that date we could choose to accept any of the applicable Regulations. In the future, many of the current national (SABS) Compulsory Standards will be superseded by the relevant ECE Regulation. It is worth mentioning that one such adopted Regulation is ECE-R83, which deals with emissions from light motor vehicles. In an historic step to better air quality, all newly homologated cars will have to comply with Euro 1 from 1 February 2005 (when Europe adopts Euro V). There will then be a phased tightening of the limits, and it is projected that we will be on a par with Europe by 2010.

WP.29 is the umbrella council for a number of "Groups of Experts" (GRs), who look at the technical implications of existing and proposed Regulations. The group of relevance to this paper, and in which the author takes part, is GRPE, the group concerned with Pollution and Energy. GRPE is currently considering a number of issues that potentially have a direct impact on the heavy-duty fraternity; the most significant being the Worldwide Heavy Duty Certification (WHDC) programme, and the Worldwide Harmonised On-Board Diagnosis (WWH-OBD) project.

WHDC

In the current scenario, there are different test cycles and different limits for Europe, America and Japan (this is also the case for passenger cars), which presents difficulties to the manufacturers who may have to supply different specification of engine or vehicle to the different markets.

To overcome this difficulty, the WHDC working party has developed two cycles – one steady-state and one transient – that will be used on a global basis. Furthermore, these cycles have been made as robust as possible, to be universally applicable, and are aimed at being as representative of on-road use as is technically possible.

The cycles have been validated on over 150 different engine types, and the programme has now entered the third stage – the Round Robin phase. A number of reference engines will be tested at laboratories all round the world, including the HDD facility at Eurotype Test Centre in East London. In this way, the repeatability and reproducibility of the two cycles will be confirmed by an extensive test sequence, prior to their incorporation in the Global Technical Regulation (GTR). Thus, South Africa has joined the global fraternity in the heavy-duty field as well.

WWH-OBD

In common with their light-duty counterparts, an increasing number of heavy trucks are being fitted with on-board diagnosis systems. There is a move to integration of all OBD functions, to warn the driver of a wide range of minor or serious problems. In terms of emissions, the OBD system will indicate that the vehicle is likely to fail a roadside test, as pollutants would exceed the allowed threshold.

Perhaps more ominously, Regulatory bodies could also use the OBD function. It may be an offence, for example, to continue a journey when the OBD unit has indicated a fault in the emission control system, beyond an allowed "limp home" concession. It would be theoretically possible for the authorities to interrogate a fault memory and determine when the malfunction was first indicated. Failure to acknowledge and rectify the fault could be punishable in law.

CONCLUSION

From the main sections above, it should be obvious that the vast numbers of internal combustion engines running today have an effect on all life on earth; either directly, through poor health incurred as a result of bad air quality; or indirectly, as a result of global warming and ozone depletion.

It should also be evident that air quality is a global problem, and all nations have to work together to address the issues of atmospheric pollution. What each country does, eventually has an effect on the rest of the world, so it is in everyone's interest to encourage and support any initiative to improve the quality of the air we breathe. In the automotive context, this means lobbying government for the rapid adoption of first-world emission standards, to match the first-world vehicle industry that we already have.

GLOSSARY

BTS	Bureau of Transport Statistics (USA)
EEA	European Environmental Agency
EPA	Environmental Protection Agency (USA)
Euro 1	ECE Regulation 83/01 or EU Directive 91/441/EEC
HDD	Heavy-duty diesel, above 12 tonnes (15 tonnes, EU)
M1	Passenger vehicle, 4 wheels, maximum 8 seats plus driver
N1	Light commercial vehicle, 4 wheels, maximum 3,5 tonnes
ppm	parts per million (volumetric measure)

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