# CLEANER FUELS FOR THE FUTURE – WHERE TO FROM HERE?

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## Abstract

Although leading in many aspects of fuel quality improvement in Africa, South Africa is however lagging major developed countries, such as Europe and the USA. There are increasing pressures locally, from *inter alia* the government and the motor industry, to make certain changes to current fuel specifications that enable alterations in vehicle technology which will lead to a reduction in harmful vehicle exhaust emissions. SAPIA is currently in the process of gathering information, through review and study, which can be used in developing a proposed long-term roadmap for future fuel specifications by means of a multi-stakeholder process. This includes a review of all available South African data linking vehicle emissions to air quality impairment, the current and projected South African car parc in addition to other studies. The results of these studies will assist in the determination of a rational future fuels roadmap for South Africa.

*Keywords*: Improved air quality, integrated approach, fuel specifications, South Africa.

## 1. Introduction

The South African Petroleum Industry Association (SAPIA) was formed in 1994 to represent the common interests of the petroleum refining and marketing industry in South Africa and now has 7 members: BP Southern Africa, Chevron South Africa, Engen Petroleum, PetroSA, Sasol, Shell South Africa and Total South Africa. SAPIA's role is to:

- promote an understanding of the industry's contribution to economic and social progress with all stakeholders,
- represent the industry in national and international forums,
- be a source of information on the Industry as a whole,
- encourage co-operation between members on matters of mutual and/or public concern without inhibiting competition (eg. health, safety and environment).

As part of the latter role, SAPIA is currently in the process of gathering information, through review and study, which can be used in developing a proposed long-term road-map for future specifications for petrol and diesel. This roadmap will need to be accepted as being in the best interests of South Africa as a whole and not only in the best interests of a single sector.

It needs to be recognised that the achievement of improved air quality requires a holistic and integrated approach. Vehicle emissions, although potentially a significant contributor to urban air quality degradation, are not the sole contributor and all other sources need to be identified and suitably managed. Similarly, the changing of certain fuel specifications in isolation will not lead to any significant improvement in vehicle exhaust emissions and improved air quality. Vehicle technology, the age of the vehicle, the condition of the engine and emission control system and driving patterns, need to be taken into account if the end goal of improved urban air quality is to be achieved.

For their part, SAPIA member companies would like to work together with the relevant regulators, as well as other interested stakeholders, to find an optimal solution in minimising the release of harmful vehicle emissions.

## 2. History of the development of cleaner fuels in South Africa

The process of introducing cleaner fuels into the South African market started with the reduction, and final removal, of lead in petrol and the reduction of sulphur levels in diesel.

Lead, in the form of lead alkyl, had been added to petrol since the 1920's to raise the octane number and so prevent engine "knock" which is the uncontrolled combustion of the last part of the fuel/air mixture in the combustion chamber. The use of lead alkyl continued globally through the 1970's, at which time mounting concern over the increasing recognition of the health effects of airborne lead eventually resulted in successive governments and regions (e.g. the EU) to ban the use of lead additives in petrol.

A major factor in removing lead from petrol was that, not only did it reduce lead itself in the atmosphere, but it enabled the introduction of exhaust catalysts to meet vehicle exhaust emission limits aimed at improving air quality. Catalysts are quickly rendered inactive when lead, carried in the exhaust gases, is deposited on the active catalyst sites "poisoning" the catalyst. Vehicle emissions increase substantially when the catalyst is poisoned.

Globally, the lead removal process started in Japan, USA and Canada in the mid-1970's. In South Africa the process started in 1986 when lead levels in petrol were reduced from 0.836 gPb/l to 0.60 gPb/l. These levels were further reduced until leaded road fuel was finally banned in January 2006 (see Fig. 1).

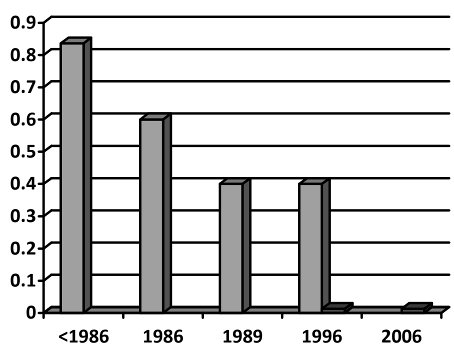



Figure 1. Reduction in lead levels (gPb/l).

During this time, not only did the lead atmospheric levels decrease, but the lead in the marine environment was also seen to decrease. The Mussel Watch Programme of the Marine and Coastal Branch of the Department of Environment and Tourism (DEAT) noted that the lead levels in black mussels, which are filter-feeders, close to the mouth of the Black River in Table Bay, Cape Town, decreased from 15.5 parts per million (ppm m/m) in 1986 to 0.6 ppm in May 1998. The lead contamination resulted from the lead in the exhaust emissions being deposited on the road and washed via the stormwater system into the river. Further reductions can be expected now that lead in petrol has been removed completely.

Similarly, the fuel sulphur levels have also been reduced. Diesel sulphur was reduced from 5 500 ppm to 3 000 ppm in 2001 and further reduced to 500 ppm in 2006, with an niche grade of 50 ppm also being introduced in a large part of the country. The sulphur level of unleaded petrol (ULP) was reduced from 1 000 ppm to 500 ppm at the time.

The determination of the new fuel specification standards was conducted through a multi-stakeholder process under the auspices of the Department of Minerals and Energy (DME).

Although monitoring data is not available to confirm that the elimination of lead in petrol and the reduction of sulphur in diesel and petrol has directly lead to an improvement in urban air quality, this will undoubtedly have enabled the introduction of vehicle technology that will reduce harmful vehicle emissions. All new homologated vehicle models were required to be fitted with catalytic converters from January 2006 and all new vehicles from January 2008, although unleaded petrol was available throughout South Africa from 1 January 1996. This allowed Euro 2 type vehicle emission standards to be achieved.

The time has now come for the existing fuel specifications to reviewed and future fuel specifications determined that will contribute to the overall objective of improving urban air quality. The DEAT will be the lead agent in this process and are expected to declare vehicles as being "controlled emitters" in terms of the Air Quality Act which will enable them to determine vehicle emission standards. The DME will then be in a position to set fuel specification standards which will enable the achievement of the vehicle emission standards.

## 3. Lessons learnt from local and international experiences.

As part of the process of determining future fuel specifications, it is essential to review previous experiences in introducing these specifications and their impact on air quality, both locally and internationally, so as to learn from previous mistakes and strengths of earlier programmes.

### *3.1 Local experiences*

DME initiated discussions on the first round of fuel specification changes, with the establishment of a multi-stakeholder group, in 2001. The new fuel specifications were launched into the market in 2002(Sulphur reduction in Diesel from 5 500 ppm to 3000 ppm), 2005(reduction in sulphur in ULP petrol from 1000 ppm to 500 ppm) and 2006 (Lead was phased out completely including further reduction in sulphur in diesel). The following can be considered to be learning experiences from the exercise:

- A multi-stakeholder process is required to ensure general "buy-in" by all affected parties.
- The decision-making process is made easier for the regulator if the various sectors can speak with one voice and present a common viewpoint.
- The required fuel specifications should be officially promulgated before firm investment decisions for refinery process changes can be made i.e. regulatory certainty is required.
- A practical lead time is required between the time that specification changes are promulgated and implementation takes place. A period of at least 5 years would now be required because of the current huge global demand for refinery upgrade resources.
- As practised globally, some kind of incentivisation is required to ensure that refineries are encouraged to invest and make the changes early so that this is staggered and not done at the last minute and all at once. Based on previous experience this may lead to a compromise in energy security.

It is important that these local learning experiences be taken into account when planning for future specification changes.

## 3.2 *International experiences*

The majority of developed countries have gone through similar exercises. SAPIA has undertaken a review of these experiences, certain of which have relevance to the South African situation:

- A "systems approach" needs to be adopted, where vehicles and fuels are seen as a system and vehicle emission reductions and fuels quality changes need to be linked to meeting air quality targets. For example, the USA simultaneously mandated exhaust system catalysts and unleaded petrol which drastically reduced oxides of nitrogen ($NO_x$), carbon monoxide (CO) and unburnt hydrocarbons emitted from exhaust tailpipes.

- In Europe, vehicle technology developments were driven by significant step changes in emissions legislation. It can be seen from Figures 2 that the biggest reduction in emissions of CO, HC and $NO_x$ was achieved by the introduction of Euro 2 emission standards, together with the enabling fuels. Subsequent moves to Euro 4 standards had much smaller incremental improvements in these emissions. The reduction in PM, HC and $NO_x$ emissions in diesel vehicles was relatively more significant moving from Euro 2 to Euro 4 vehicle technology, as can be seen in Figure 3.

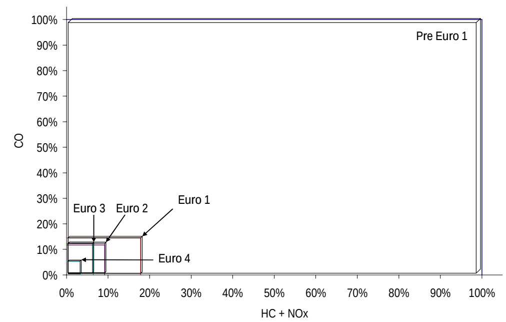



Figure 2. Plot showing the relative reduction in emissions limits of the European emissions legislation for petrol vehicles.

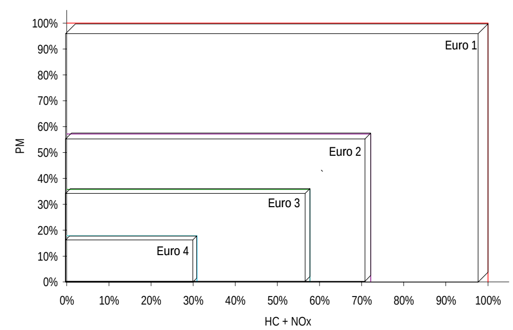



Figure 3. Plot showing the relative reduction in emissions limits of the European emissions legislation for diesel vehicles

- The relationship between fuel quality changes and engine technology changes needs to be taken into account. The effects of fuel quality changes in isolation of changes to vehicles are relatively small compared with reductions achievable from changes to engine technology. The real benefits of fuel quality changes are achieved when they are used to enable improved vehicle technology. "Clean fuels will not make a dirty engine clean".
- A holistic, integrated approach needs to be adopted in order to achieve a reduction in harmful vehicle emissions. Not only do

vehicles and fuels need to be addressed, but other aspects such as traffic management schemes, improvement in public transport and the introduction of Inspection and Maintenance (I&M) schemes need to be adopted. Vehicles when sold may conform to certain emission standards but this might not be the case as the vehicles ages. It is known that many catalytic converters are removed from vehicles in South Africa in the belief that engine performance is improved. This results in them reverting to major emitters. In this regard DEAT needs to be applauded for developing the model black smoke testing by-law which will be adopted by many local authorities. Similarly, mandatory emission testing programmes need to be put in place as part of regular road-worthy testing. This has been adopted by many countries in Europe and the USA.

- Any vehicle emissions reduction strategy needs to be designed to solve a particular region's specific air quality and vehicle emission problems. For example, due to Europe's large diesel passenger car fleet, particulate matter (PM), $NO_X$ and oxides of sulphur ($SO_X$) emissions coming from diesel engines were more of an issue than CO or hydrocarbon (HC) air toxics as identified in the USA. Carbon dioxide ($CO_2$) has now become Europe's main emissions driver. Different strategies were therefore adopted to address the different areas of concern. Similarly, it would make sense for South Africa to adopt a fuel quality strategy that has been "tailor-made" to suit the local air quality objectives, specific vehicle fleet, the unique fuel sources (ie gas-to- liquid and coal–to-liquid fuels) and the local high altitude conditions.
- Sound science is needed to form the basis of any air quality management approach. The European Auto Oil Programmes formed the basis of the final legislative proposals from the European Commission. These Programmes were founded on three key scientific and technical pillars:
  - Air quality modelling study
  - A technical research programme "European Programme on Engines, Fuels and Emissions" (EPEFE)
  - A cost effectiveness modelling study.

  SAPIA is in the process of reviewing the scientific information available on which to base a sound fuel quality strategy.
- Many countries have adopted different diesel specifications for on-road diesel and off-road diesel (i.e. that used by agricultural or construction machinery, fishing vessels etc.) The greatest portion of diesel in South Africa is used off-highway and should be considered differently to that used on the roads, with different specifications applying.
- Japan, Europe and the USA determined that from the perspective of environment, health and vehicle technology enablement, the following fuel parameters were the most important:

  **Petrol**

  - Reducing benzene to reduce carcinogenic emissions
  - Reducing volatility to reduce evaporative emissions
  - Reducing sulphur to improve catalytic converter efficiency and reduce PM.

  **Diesel**

  - Reducing sulphur to improve PM, $SO_X$ and $NO_X$ emissions
  - Total aromatics, PAH, final boiling point and cetane number can also affect particle formation and may need to be tightened.

  It was however noted in the European studies that different vehicle categories have different responses to changes in fuel properties. For example, increasing cetane number in diesel fuels lowers $NO_X$ emissions only in heavy duty and light duty direct injection (DI) engines but not on light duty indirect injection engines (IDI).
  Both the European Commission (main institution in charge of drafting legislation) and the Australian Commonwealth Steering Committee (oversaw the setting of new fuel specifications) believed that the implementation of new fuel quality and vehicle emission requirements should not be implemented unless all stakeholders were part of the legislative drafting process. It is recommended that a similar process be adopted in South Africa.

Clearly, there is much value in considering the experiences of other countries going through the same process, but the many unique conditions found in South Africa still need to be taken into account. For this reason, SAPIA is in the process of undertaking reviews and studies to clearly understand the local conditions which will have an influence on our own future fuel requirements.

## 4. Work being undertaken by SAPIA

SAPIA has formed a Work Group to identify the gaps in knowledge that SAPIA believes need to be filled in order to have sufficient information to assist in the development of a sound strategy for the proper management of vehicle emissions in South Africa. Independent contractors undertake the studies that have been identified.

The main studies that have been identified follow. The majority of these still have to be completed.

### 4.1 *Review of South African air quality impact studies relating to vehicle emissions.*

This study was undertaken by Airshed Planning Professionals who reviewed 16 studies including the Cape Town Brown Haze Studies, the NEDLAC Dirty Fuels Study, the Vaal Triangle Airshed Priority Area study and other municipal monitoring data.

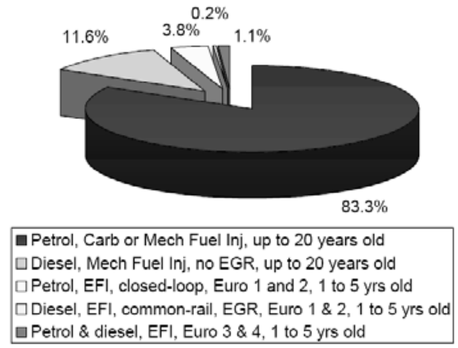
The study found that most of the information available for review was limited to pre-2006 studies, prior to the fuel formulation changes that took place in that year. It also concluded that although the potential harmful effects from vehicle emissions were well recognised from studies conducted in other parts of the world, no conclusions could be reached from the South African data on specific fuel parameters relating to poor ambient air quality. The study recommended that a better understanding should be established of the air quality benefits obtained from the 2006 fuel improvements, the impact of traffic management in urban areas should be investigated, selected urban emissions inventories be established and direction be taken from an international literature review.

### 4.2 *Review of the interaction and contribution to clean air of fuel specifications, inspection & maintenance and vehicle technology.*

Undertaken by SABS: Transportation, this study reviewed the current vehicle parc in terms of numbers, the engine technology, the resultant emissions and the possibilities of reducing these emissions by maintenance, adjustment or the retrofitting of exhaust after-treatment systems.

The study highlighted the following:

- Petrol, carburetted and mechanical fuel injected vehicles of 20 years and older, contributed 83.3% of vehicle emissions (See Fig 4)
- It is clearly not possible to replace these vehicles overnight but an incentivised approach whereby motorists are encouraged to move to lower polluting vehicles by means of a combination of taxation and subsidies could provide a solution.
- Diesel, mechanical fuel injected vehicles which are 20 years and older contribute 11.6% of vehicle emissions (See Fig 4).
- Technically, it would be easier to achieve reductions in emissions from these vehicles. Fitment of oxy-cats would reduce HC and CO emissions by around 40% to 60%. Fitment of Diesel Particulate Filters would also reduce particulate emissions.




(SABS Commercial – these figures have been extrapolated from data on vehicles sold, average kilometres travelled and available emissions data, and therefore their absolute accuracy cannot be guaranteed.)

Figure 4 – Pie chart showing percentage contribution to vehicle emissions by engine technology

- Vehicle Inspection and Maintenance programmes are essential to ensure that that pollution control systems are working.
- Intelligent traffic control systems, efficient public transport systems, educating motorists to change polluting diving habits, etc will all contribute to lower vehicle emissions.

### 4.3 *Understanding the current and future (forecast) South African vehicle parc.*

A review is currently being undertaken of the breakdown of the various types of vehicles presently in the South African vehicle parc together with a forecast of what the vehicle parc will look like in the future. This information will be used to forecast the fuel requirements of the vehicle parc now and into the future and also to give an idea of the levels of emissions from each component of the vehicle parc.

4.4 *Understanding the impact of different approaches to managing vehicle emissions in South Africa.*

The project is still in the planning phase and is being designed to model the potential impact various interventions will have on vehicle emissions and urban air quality. These interventions include changing fuel formulations, changing vehicle technology, introduction of vehicle inspection and maintenance programmes, introduction of traffic management schemes, etc. The intention of this project is to provide data on the most effective approaches in reducing the contribution of vehicle emissions to impaired urban air quality.

4.5 *Compilation of a Reference Guide on petrol and diesel specifications and the drivers behind the application of these in different parts of the world.*

It is envisaged that this Guide will provide a review of international and local trends, and the drivers for these trends in setting the most suitable fuel specifications for the different regions. The environmental, health, safety, logistical and consumer implications will be considered in this review.

## 5. A proposal for the way ahead

A great deal can be learnt from the experiences of other countries in regulating vehicle technology and the enabling fuels to meet their identified air quality goals. However, care needs to be taken in adopting these lessons in the South African context due to the number of unique factors that prevail in this country i.e. very large old sector of the car parc, large portion of the car parc operating at high altitudes and competing socio-economic priorities.

Nevertheless, it is important that these past experiences, adapted to local conditions be taken into account when developing a sound Vehicle Emissions and Fuels Strategy. It is hoped that the information currently being compiled will assist in this regard.

It is suggested that the formulation of a Vehicle Emissions and Fuels Strategy should involve a multi-stakeholder process so that buy-in can be obtained from all the relevant stakeholders. These should include:

- Relevant government departments; Environment Affairs and Tourism, Minerals and Energy, Transport, Health Trade and Industry, Finance.
- Fuel producers
- Vehicle manufacturers and importers.
- Vehicle and fuel end-users.
- NGO's and community-based groups.

It is further recommended that this process start as soon as possible as it will take some time to determine the optimal vehicle technology / fuels mix for South African conditions and then at least five years to make the necessary refinery / logistical changes to introduce these fuels with the revised specifications into the market place.