The environmental significance of the introduction of new fuel legislation in South Africa

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Summary

In May 2002 the South African Department of Minerals and Energy announced that new fuel legislation will come into effect in 2006. The legislation entails the total phase out of leaded petrol and a reduction in the allowed sulphur level in diesel by January 2006. This mini-dissertation aims to determine the environmental significance of the changed legislation, focussing on the impact of the new legislation on air quality, the subsequent health impact and the secondary effects it may result in. It also suggests mitigation measures to ensure a significant positive impact on air quality.

This mini-dissertation presents an overview of the initial introduction of lead to fuel, the global phase out of lead, and the phase out development in South Africa. The impact of the legislation on the different sectors of society is discussed. This includes the impact on the fuel manufacturing industry and the impact on motor vehicles and their owners. A discussion on possible additive alternatives is also included. The proposed implementation of the new South African Vehicle Emission Strategy together with the vehicle emission legislation is discussed. The South African health impact as a result of the reduction in lead is investigated comparing it to international tendencies.

It is concluded that the implementation of the new legislation will be challenging in the light of South Africa's specific conditions. The long term effect on air quality is thought to be positive and would therefore potentially result in a significant improvement in general health. There may however be some interim problems with the older South African motor vehicle fleet. Mitigation measures will have to be implemented to ensure an effective implementation of the legislation.

Opsomming

Die omgewingsbeduidenheid van die implementering van nuwe brandstof wetgewing in Suid Afrika

Die Suid-Afrikaanse Departement van Mineraal en Energiesake het in Mei 2002 aangekondig dat nuwe brandstof wetgewing in 2006 in werking sal tree. Die wetgewing behels die uitfasering van geloodte petrol en 'n verlaging in die toegelate swael inhoud van diesel vanaf Januarie 2006. Hierdie skripsie ondersoek die beduidende invloed van die nuwe wetgewing op die omgewing. Daar word gefokus op die impak op lugkwaliteit en die verwante gesondheidsimpak, asook die moontlike sekondêre effekte wat dit mag teweeg bring. Die skripsie stel ook mitigeringstappe voor wat geïmplementeer kan word om 'n algehele positiewe impak te verseker.

Die skripsie gee 'n oorsig van die gebruik van lood in brandstof, die globale uitfasering daarvan en die Suid-Afrikaanse uitfaseringsverloop. Die impak op die verskillende sektore van die samelewing word bespreek. Dit sluit in die impak op die brandstof vervaardigingsindustrie en die impak of motorvoertuie en hul eienaars. 'n Bespreking van moontlike bymiddel alternatiewe is ook ingesluit. Die voorgestelde implementering van die beplande Voertuig Emissie Strategie en die voertuig emissie wetgewing word bespreek. Die Suid-Afrikaanse gesondheidsimpak as gevolg van die wetgewing word ondersoek en vergelyk met internasionale neigings.

Die gevolgtrekking word gemaak dat in die lig van die unieke Suid-Afrikaanse situasie, die implementering van die nuwe wetgewing uitdagend mag wees. Die lang termyn effek op lugkwaliteit behoort positief te wees en dus potensieël 'n verbetering in algemene gesondheid teweeg te bring. Daar mag egter in die interim probleme wees met die ouer Suid-Afrikaanse motorvoertuig vloot. Spesifeke mitigeringsstappe sal toegepas moet word om 'n effektiewe implementering van die wetgewing te verseker.

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1. Introduction

South Africa, as many other third world countries, is lagging behind the rest of the world with regard to the management of pollution. Specifically the management of air pollution has fallen behind here due to the fact that there have been more urgent matters to attend to such a basic health care and the relief of poverty. Funds for the implementation of new technologies and mitigation measures to combat pollution have simply not been available. The use of coal is probably the primary source of air pollution in the country. It is widely used in the both the commercial and domestic sectors. In urban areas vehicle emissions however also contribute significantly to the problem of air pollution. The lack of vehicle emission legislation in South Africa has lead to the prolonged use of older generation fuels and the absence of vehicle emission control systems.

In modern society fuel has become imperative for standard living. Fuel is required for the transport of all consumables ranging from essential items such as food and medical supplies to luxury items. Fuel burning vehicles are used widely in both the commercial and private sectors. It has become a familiar chemical in everyday life both in developed and developing countries.

In recent years it has however become increasingly apparent that commercial fuel has had a negative impact on human health for decades. According to Pressdee (1990:41) motor vehicles are responsible for as much as 40% of all atmospheric pollution. The standard internal combustion engine burns fuel to generate power. Unfortunately by-products including carbon monoxide, hydrocarbons, NO_x emissions and heavy metal particles are formed during this process (Anon., 1990:41). These products enter the environment through the exhaust fumes of vehicles and have a variety of negative impacts on human health.

According to the South African government the contribution of vehicle emissions to air pollution can no longer be ignored. The number of vehicles on the South African roads is increasing, contributing to the escalating problem of urban air pollution (SA, 2003:14). Due to the absence of vehicle emission legislation many South African vehicles are emitting much more harmful substances than their developed world counterparts. Many vehicles are also old and in poor condition, further contributing to the problem (SA, 2003:4).

One of the main contributing factors to vehicular air emissions is the fuel used to power motor vehicles. In May 2002 the South African Department of Minerals and Energy announced that new fuel legislation would come into effect in 2006. The legislation entails the total phase out of leaded petrol by January 2006. Together with this the allowed sulphur level in diesel will be reduced from 3000 to 500 parts per million (Gosling, 2002:2). This announcement follows the global trend of mitigation measures aiming to phase out leaded petroleum and reduce sulphur levels in diesel.

The potential harmful effects of lead and sulphur on human health is recognized and widely published. Exposure to lead is known to cause hyperactivity, decrements in IQ, shortened concentration span and hearing loss among many other health effects (Mathee, 2003:29). Sulphur creates SO_2 emissions and particulate matter, contributing to respiratory diseases and the creation of photochemical smog (Gosling, 2002:2).

In South Africa the average local motor vehicle is old in comparison to international counterparts. This contributes further to air pollution since most of these vehicles are not fitted with emission control devices as their international counterparts. These emission control devices are in turn dependant on suitable fuel, and therefore the first step in tackling the vehicle emission problem in South Africa is the introduction of cleaner fuels. This forms part of the government's vehicle emission regulation strategy to improve the general quality of air of particularly the urban areas (SA, 2003:4). South Africa's situation is therefore somewhat unique since the out phasing of conventional fuels is driven from both an environmental and a technological point of view.

The reason for the new legislation is understandable. Elimination of harmful substances from fuel will have a positive effect on air quality and therefore also on human health. The issue is however not as straightforward as it would initially seem. With a change in legislation of this magnitude many secondary effects are created. These effects will impact on many sectors of the South African society.

The first segment impacted is the fuel industry. Fuel manufacturers are probably most affected by the changed legislation. These industries are obligated to implement novel manufacturing methods in order to meet the new fuel specifications. This requires redesigning of existing factories, which necessitate a huge financial investment. Different from standard modifications, which usually produce a reasonable return on investment, this capital expenditure does not result in any financial gain to the industry. The required modifications therefore result in a financial burden on the side of the manufacturer since shareholders of these companies still demand return on their investment.

The second affected sector is the community of vehicle owners. The average motor vehicle owner is generally resistant to change. Since the introduction of unleaded fuel in South Africa in 1996 the greater majority of motorists still prefer leaded fuel. Although it is estimated that 80% of local vehicles are able to use unleaded fuel, currently only 30% of vehicles do so (Khulu, 2005:1). Motorists are concerned about performance and fuel efficiency with the use of unleaded fuel (Anon., 2003:21). Many earlier manufactured vehicles are not able to use unleaded fuel for long periods due to valve seat recession. In general motorists seem to have some doubt regarding the reliability of the newly introduced fuels.

Lastly the general public will be affected by the proposed changes. With the elimination of harmful substances from fuel, the effect on human health is proposed to be positive. Simply changing the fuel is however not enough. Emission control systems need to be fitted to vehicles in order to have a significant positive effect and in South Africa this will most likely be challenging.

The aim of the new legislation is therefore clear, eliminate harmful substances from fuel and improve the quality of air to ensure a safer environment for all. The question is however whether this is enough and what secondary effects the change may bring about.

2. Aim of the study with research questions

The intent of the new fuel legislation announced in May 2002 by the Department of Mineral and Energy Affairs is generally perceived as being aimed directly at the elimination of specifically lead and sulphur. Although this is true it is not the only benefit of the phase out. Apart from eliminating lead deposits, the use of unleaded fuel has the further secondary benefit of enabling all vehicles to be fitted with catalytic converters. According to the International Petroleum Industry Environmental Conservation Association (IPIECA), this is probably the most significant benefit of the introduction of unleaded fuel (IPIECA, 2003:6).

Unleaded fuel will also have an economic benefit. According to Hashiso and El-Fadel (2001:400), the benefits from the phase out of lead from gasoline are both health related and technology related. Unleaded gasoline provides a cost benefit as a result of reduced car maintenance since lead causes corrosion of exhaust systems and engines. The change to unleaded petrol can therefore increase engine life significantly (Hashiso & El-Fadel, 2001:402). This is however only applicable to newer vehicle models.

Another issue to take into consideration is the current emission levels of vehicles in South Africa. According to the government South Africa is specifically targeting the introduction of cleaner fuel, because of the fact that the majority of vehicles are not fitted with emission control systems (SA, 2003:14).

The benefits from the phase out initiative are clear. What is not clear is whether the elimination of these substances will contribute significantly the quality of ambient air in South Africa.

Although leaded fuel contributes significantly to lead deposits in the environment, it is not the only source. Other key sources are the lead used in paint; plumbing and lead transfer from lead industries into households (Mathee, 2003:29). It therefore still needs to be proved that the phase out of leaded petrol will have the desired effect of minimising lead particulates in the environment.

A third aspect to consider is the price to be paid for the phase out. As mentioned, a huge amount of capital will have to be spent by the fuel manufacturers to modify their existing production facilities. From an economic point of view it has been stated that the cost of converting the existing refineries to meet the new standard will amount to between ten and fifteen billion rand (Robertson, 2003:7).

With the phase out of lead, new additives need to be developed. These substances need to be evaluated carefully to ensure that they do not cause further detrimental effects on human health and the environment. Fortunately, lead is not the only way to boost octane. However, the alternatives, although better, still have their own drawbacks. *Sasol* has been using a manganese based additive methylcyclopentadienyl manganese tricarbonyl (MMT) in its *dualfuel* since 2002. This additive is controversial since manganese is also a toxic metal (Hodes & Thomas, 2003:9). The aromatic compounds sometimes used as additives are known carcinogens. The problem facing industry is whether one harmful substance is not simply replaced by another. It has also been indicated that cleaner fuels are only effective if they are used in vehicles fitted with emission control systems. The average South African vehicle is not and will probably not be for several years. This is due to the longer lifetime of local vehicles compared to those in developed countries.

The intent of this dissertation is to determine the environmental significance of the introduction of the new fuel legislation. Firstly the impact of the introduction of new fuels needs to be determined. Its contribution to the improvement of air quality needs to be established.

Secondly the secondary effects of the phase out will be investigated. This includes the impacts that the new legislation will have on the petroleum industry and the development of alternative additives.

The three questions that need to be answered are:

1. Whether the new legislation will have a significant positive effect on the current air quality and therefore on the health of the general public;

2. What secondary effects the new legislation may bring about;

3. What additional mitigation measures have to be implemented to ensure an overall positive effect on ambient air quality?

3. Literature review

3.1 Lead

Man has used lead for centuries. In Roman times it was commonly used in water and wine containers. More importantly lead was used for the majority of plumbing throughout the Roman Empire. It was even used as seasoning for food. It is believed that lead poisoning was the reason for the known sterility among aristocratic males and the high rate of infertility among aristocratic women of the time (Lewis, 1985).

The first account of lead poisoning was reported as early as 370BC. The exposure to environmental lead was accelerated by the industrial revolution. Workers were increasingly exposed to the metal by smelting, painting, plumbing and printing industries (Tong et al, 2000:1068). Cases of lead poisoning increased and in 1883 the United Kingdom (UK) introduced the Factory and Workshop Act, which introduced certain minimum standards for lead factories.

It is estimated that worldwide the current exposure of man to lead is three hundred to five hundred times greater than the natural levels. Annually 332 000 tons of lead is introduced from anthropogenic sources (Diab, 1999:117). The Unites States Agency for Toxic Substances and Disease registry has estimated that 90% of the lead currently present in the atmosphere is the result of burning leaded gasoline (Kitman, 2000).

Lead is a soft greyish heavy metal, which is odourless and tasteless. Its unique properties of being malleable and resistant to corrosion have led to the widespread use of the metal (Mathee & von Schirnding, 1999:14). It is indestructible and also non-biodegradeble (Environmental Protection Agency, 1999). Unlike many other toxic chemicals, lead does not break down over time and is relatively insoluble in water. It is soluble in weak acids and in "aggressive" waters.

Lead can be present in the atmosphere in one of two forms, either as solid dust particles of lead dioxide, or in a gaseous form as alkyl lead which originates from evaporation from petrol. Depending on the size of the particles, it can be inhaled and penetrates deep into the lungs. Once it is absorbed it is transported to the rest of the organs and tissue by means of the bloodstream (Diab, 1999:117). Since lead does not break down, it accumulates in the body and has a harmful effect on human health, particularly on that of children (Tyler Miller, 2002:423). They are more susceptible since their physiological uptake rates are higher than that of adults. Their average intake of lead per unit body weight is also higher than that of adults (Tong *et al*, 2000:1069).

With children the main route for entering the body is by ingestion of lead-rich dust (Von Schirnding, 1990:23). Lead particles accumulate on the ground and children playing in high-risk dusty areas, often ingest lead by normal playing activities through the so-called "hand to mouth" or "pica" pathway. They may also ingest it by biting their nails or sucking their fingers (Mathee & von Schirnding, 1999:14).

Lead poisoning is the direct result of a too high level of lead in the body. As mentioned an individual can be exposed either through inhalation, dermal absorption or ingestion. The lead replaces other metals and minerals in the body including iron and calcium, which are essential for growth and development of the human body. Since growing children require more of these minerals, they are therefore more vulnerable to lead poisoning (Environmental Protection Agency, 1999). The lead concentration of soft tissue in the human body can stabilise over time, but lead is also stored in bone, from where it can be mobilized (Ellison *et al*, 1991:383).

Lead has many adverse effects on human health. It is a neurotoxin which creates a vulnerability to nervous system impairment, a lowered IQ, a shortened attention span and can even lead to hyperactivity and hearing damage (Tyler Miller, 2002:540). According to Mathee and von Schirnding (1999:14) foetal exposure has been associated with abnormal development of organs and low birth weight. Many of these health effects from lead exposure are irreversible in young children. Apart from affecting the health of children it can also cause high blood pressure, kidney malfunction and cardiovascular problems in adults (Ellison *et al*, 1991:386).

It is further important to note that even low levels of lead exposure can be significantly harmful. For very long lead was thought to be safe in low dosages. It was only recently that the real danger was discovered. The advancement in toxicology and laboratory technologies in recent years has led to the realisation that lower levels not known to be significant previously is now recognised. The World Bank has also ranked lead as one of the most serious environmental threats to human health (Gosling, 2002:2).

According to Mathee and von Schirnding (1999:14) there is a wide range of sources of lead, particularly in urban areas. Leaded fuel is therefore not necessarily the only contributing factor to the high lead levels in the environment.

Lead exposure can be traced to a variety of sources. Among adults the greatest source of lead poisoning is in lead related industries. These include motor vehicle assembly, panel beating, battery manufacturing, and soldering. Lead mining and smelting and lead alloy production are also important sources. In developed countries strict control of working conditions prevent exposure, but in developing countries little control is applied. The ceramics and pottery industry also poses a high risk. These industries have the added disadvantage that they are often home-based businesses, exposing children as well as adults (Tong, 2000: 1070).

Small businesses are not as strictly controlled and often the workers are not informed of the health risks that they expose their families to.

Lead has been used widely in paint, and lead-based paint has been recognised as a high dose source of lead absorption, causing lead poisoning in young children (Marino & Landrigan, 1990:1183). According to Lanphear (1998:1618) paint seems to be the major source of childhood lead poisoning in the USA. Lead was used as a pigment in paint since the early 1800's. It was used widely until the 1940's. With the introduction of latex based paints the use of lead declined. In 1978 the allowable level of lead in the USA was lowered to 0.06%. Many buildings built prior to 1950 however still contain lead based paint.

The problem with these paints occurs when the paint starts to deteriorate. Chipping and peeling leads to the formation of a very fine dust, which is not visible to the naked eye. It is this dust that poses a huge threat of lead poisoning, usually during renovation work. This can be inhaled or children may ingest it by chewing on objects covered by the dust (Environmental Protection Agency, 1999).

In a case report done by Marino *et al* (1990:1183), the lead poisoning of an American family as result of the renovation of their house is described. The house was a Victorian farm house which, through the years, had been painted with multiple layers of lead based paint. Paint was removed using both sanders and heat guns. The first sign of poisoning was the family dog getting ill. Lead poisoning was diagnosed and it was then discovered that the whole family, adults as well as children, had elevated blood lead levels. They all required treatment. The mother of the family was eight weeks pregnant at the time and because of the severe exposure underwent a therapeutic abortion.

The process of renovation produced paint chips, fine dust particles and fumes. The fumes caused by the use of heat guns and torching are especially dangerous because they can easily be inhaled. Even if leaded paint is not being used anymore the potential risk of exposure to old paint sources is still present. As depicted in the case study, most of the inhabitants of old homes are not even aware of their potential exposure (Marino *et al*, 1990:1184).

Another form of lead exposure is through food. Food sold in tin cans can be contaminated with lead through lead soldered cans (Environmental Protection Agency, 1999). Some leaded glassware and dishes may also release lead. Vegetables grown in soil with a high lead content can absorb it and in this way humans can be exposed. Lead particles can also be transferred from work to households by workers working at lead industries (Mathee, 2003:29).

Pipes used for the routing of drinking water often contain lead or lead solder. Through this route lead poisoning can occur from water coolers, taps and drinking fountains that contain lead lined tanks or lead soldered joints (Environmental Protection Agency, 1999).

In local research done by Von Schirnding in 1989, it was found that the blood lead levels of South African children are affected by several factors. This includes a variety of sources such as air, water, paint and dust (Von Schirnding, 1989). It has also been determined that there is a strong relation between urbanisation and raised blood lead levels, both locally and abroad (Von Schirnding *et al*, 1991:454). The environmental lead levels were found to be significantly higher in areas with heavy traffic, indicating that leaded fuel is a significant contributor to elevated blood lead levels.

According to the World Bank (1996) leaded fuel is the cause of 90% of the airborne lead pollution in cities. Lead is emitted through the exhaust fumes of vehicles using leaded fuel. Lead particles are therefore deposited into the air and dust and soil located in close proximity to roads (Mathee & von Schirnding, 1999:14). There is therefore a significant relationship between traffic density and human blood lead levels (Ellison *et al*, 1991:386).

In a study done in Shantou, China, it was proved that leaded fuel was in fact one of the major contributing factors to high blood lead levels. The use of leaded gasoline was prohibited in this city at the end of 1998. Children were monitored for three consecutive years, showing a remarkable drop in blood lead levels from 1999 to 2001 after the phase out of lead in a specific city (Luo *et al*, 2003).

Similar findings were made in the United States. In 1976, before the phase out of leaded fuel, the average blood lead level of Americans was 16ug/dl. In 1980 in decreased to 10ug/dl and in the 1990's to 3ug/dl (World Bank, 1996:3). The elimination of lead from fuel therefore seems to have a definite positive effect on average blood lead levels.

3.2 The Introduction of lead to fuel

The form in which lead is introduced to fuel is tetraethyl lead (TEL). A German scientist first discovered it in 1854 (Kitman, 2002). Even then it was known that contact with the substance could cause hallucinations, trouble breathing and even death.

In the early 1900's the General Motors (GM) Corporation in Ohio experienced problems with engine "knocking" in their vehicles. Engine knock reduces engine efficiency and leads to an increase in heat load on a vehicle's cooling system (IPIECA, 2004:7).

Initially it was thought that this phenomenon was caused by electric components. Charles Kettering, one of GM's engineers was however convinced that the fuel used caused the knock effect. He and his assistant, Thomas Midgley Jr., performed intensive research into solving the problem of engine knock. It was eventually discovered that the problem was in fact premature combustion of the fuel/air mixture and that this was directly related to the explosive quality of the fuel used. This explosive quality would later become known as the octane value or rating. With the problem identified the search for a fuel additive that would be able to increase this octane rating of fuel commenced (Kitman, 2000).

Today the octane value of a fuel is determined by comparison of the tested fuel with a blend of iso-octane and heptane. Iso-octane is assigned a value of 100, with heptane a value of zero. Different blends of these two chemicals are then made. The tested fuel's performance is compared to the performance of these blends and then assigned a research octane number (RON) and a motor octane number (MON). The higher the octane number of the fuel, the better the fuel's resistance against engine knock (IPIECA, 2004:24).

In the early 1920's ethanol was discovered to be the desired octane enhancing product. It was reported to reduce engine knock with the added advantage that it was non-toxic and clean burning.

The General Motors fuel research department was however under pressure. The problem with ethanol was that GM could not supply it in the volumes required. Furthermore it could be manufactured by basically anyone. The company would not be able to control the market and producing alcohol was also expensive. The research department was pressurised to come up with a technological breakthrough that would provide GM with a competitive advantage (Kitman, 2000).

In 1921 the engineers from GM reported success in their trials performed on tetraethyl lead (TEL) (Lewis, 1985). Suddenly the focus shifted away from ethanol. Unlike ethanol, TEL could be patented, and it would therefore provide an incentive for GM to promote the product. A patent for the production of TEL was filed and initial work for larger scale production commenced.

In 1923 the first commercial TEL was produced and used in vehicles. Although there was much controversy regarding the known toxin in the early 1920's, General Motors succeeded in convincing the public that TEL was harmless. Emphasis was rather placed on the many superior performance qualities of the additive. TEL had the added advantage that it had lubrication properties which protected the valve seats of an engine (IPIECA, 2004:24). According to Kitman (2000) it was added to 90% of gasoline sold in the USA by 1936.

TEL was introduced to Europe in the late 1930's and after World War II, also started spreading to other world markets. For decades TEL was therefore used without much concern.

3.3 Global phase out of leaded fuel

Although it was only during the last few decades that the phase out of leaded fuel began, it is not a new school of thought. As early as the 1920's the use of lead in gasoline was opposed by Alice Hamilton, an expert in the field of industrial disease in the United States at that time (Tyler Miller, 2002:540).

According to Lewis (1985) many of the researchers working with TEL suffered illnesses. News of this reached the press and in 1925 the Surgeon General of the USA temporarily suspended the use of leaded fuel. A team of scientists were assigned to conduct a study on the effects of TEL. They were however given a very limited time period, which led to a report with inconclusive results being issued. It mentioned the tight schedule and proposed that more in-depth investigation was required. This was however never followed up. Since no scientific proof of its harmful effects was available, fuel-manufacturing companies continued to use TEL in their products.

In 1965 dr Clair Patterson published his work "Contaminated and Natural Lead Environments of Man". It provided the first scientific proof that the high background levels of lead in industrial areas were in fact man made. This was the first step to the downfall of the TEL industry (Kitman, 2000).

In 1971 the first administrator of the newly formed United States Environmental Protection Agency (EPA) declared that the use of TEL in fuel does in fact result in the production of fine lead particles that is potentially harmful to human health (Lewis, 1985). In 1974 the EPA announced a scheduled phase out of leaded gasoline. Although they received some initial opposition, the first phase out programs commenced in 1976 (Kitman, 2002). It started with the reduction of lead from 2 grams per gallon to 0.5 grams from January 1979.

In response to the phase out of leaded fuel, automobile manufactures in the USA started equipping vehicles with catalytic converters which were designed to run on unleaded fuel. The phase out of lead also set the stage for the phase out of other substances such as sulphur. In 2001 the EPA introduced new sulphur limits, which will also come into affect in 2006.

The USA initiative started a global trend of phase out of leaded fuel in developed countries. This was achieved by the following measures (Octel, 2005):

1. A reduction in the allowable concentration of lead in fuel.
2. An increased availability of unleaded fuel.
3. The introduction of incentives to promote the use of unleaded fuel.
4. Total phase out of leaded fuel by certain dates.

In May 1986 the World Bank called for the global phase out of leaded fuel. According to the managing director of the organisation at the time, Mr. Caio Koch-Weser, children would be the main beneficiaries of the phase out since it was them who suffer disabilities as result of lead exposure (World Bank, 1996).

In Britain the phase out began in the late eighties, with the European Union banning leaded gasoline in 2000.

In 1994 the United Nations Commission on Sustainable Development formally requested governments around the world to commence with actions to phase out leaded fuel (Earth Summit Watch, 2004:1). This led to the worldwide initiation of phase out programs. Organisations such as the World Bank and OECD also implemented action plans aimed to assist third world countries in this process.

Table 1.1 shows the planned phase out in leaded fuel in different countries as predicted in 1999.

Table 3.1 – Leaded Fuel Phase Out Schedule (Earth Summit Watch, 1999:2)

Time Period:	Already	2000	2001-2003	2004-2006
Countries:	Argentina	United Kingdom	Ecuador	Greece
	Austria	France	Egypt	Spain
	Bahamas	Trinidad and Tobago	Ireland	Portugal
	Belize	Taiwan	Italy	Peru
	Bermuda	Monaco	Jamaica	Bulgaria
	Bolivia	China		Australia
	Brazil	Belgium		Romania
	Canada	Philippines		India
	Colombia	Switzerland		Mexico
	Costa Rica			Chile
	Denmark			Czech Republic
	Dominican Republic			Poland
	El Salvador			Hungary
	Finland			Bangladesh
	Germany			Nepal
	Guam			**South Africa**
	Guatemala			
	Haiti			
	Honduras			
	Hong Kong			
	Hungary			
	Iceland			
	Japan			
	New Zealand			
	Nicaragua			
	Norway			
	Puerto Rico			
	Singapore			
	Slovakia			
	South Korea			
	Sweden			
	Netherlands			
	Thailand			
	United States			
	US Virgin Islands			
	Luxembourg			

In 1999 it was estimated that 78% of all fuel consumed was unleaded and if the planned phase out is successful, 84% will be lead free by the end of 2005.

Internationally taxation incentives have been used to encourage the use of unleaded fuel during the transition phases. This enables the subsidising of the production of unleaded fuel which is more expensive to produce. This concept seems to work well in developed countries, but it is often perceived as unfair trade in developing countries. The perception develops that owners of older vehicles who are unable to use unleaded fuel are being penalised. This incentive is therefore only effective in selected countries and the local cultures and infrastructure needs to be taken into account prior to implementation (IPIECA, 2003:19).

To a large extent developed countries have made the transition, but many developing countries are still using leaded fuel. With the phase out in developed countries many international producers specifically targeted developing countries as an export market (Brooke, 2000:27). The countries were mainly situated in the Far East, the Middle East and South America (Kitman, 2002); developing countries where environmental legislation was not yet so strict. Africa was also a target. In 2002, 93% of all fuel sold in Africa was still leaded. This led to the current situation where 80% of the heaviest leaded fuel-using countries are low-income countries.

Octel, the main manufacturer of TEL, continues to supply the product to countries in the midst of phase out programs. They also provide decontamination and recycling services to refineries after transformation to unleaded fuel (Octel, 2005).

According to the Global Lead Network (2004) Africa is more affected by lead poisoning and pollution than any other continent. Most counties in Africa still use leaded fuel of which the lead content is of the highest in the world. The people of these countries' exposure to risks are elevated due to the dusty conditions of roads and towns. This increases the ambient transport of lead and increases the probability of exposure. A further drawback is the fact that due to the lack in air quality legislation, there is no incentive for the introduction of catalytic converters. The rapid growth in automobile use further contributes the detrimental effect on the air quality in these countries.

In the light of this situation the World Bank in co-operation with AFRICACLEAN, initiated a project to combat the problem. This project will support the implementation of the Declaration of Dakar, which aims to have leaded fuel phased out in Africa by 2005. It aims to focus on fuel importing countries. In this way pressure can be applied on the fuel manufacturers to phase out leaded fuel (Global Lead Network, 2004).

With TEL not present in fuel to boost the octane value there is a concern that it will result in higher benzene and aromatic concentrations to boost octane. It is therefore important that fuel specifications prescribe maximum levels for benzene and aromatics. The idea is that the concentration of benzene must gradually be reduced to between 1 and 2 % and that of aromatics to between 40 and 50 % (IPIECA, 2003:8).

Developing countries often lag behind in the required technologies to produce fuels of this nature. Their refineries often do not have the required alkylation or isomerisation capacity and they also have relatively small reforming capacity. This results in the production of either fuel with lower octane numbers and/or fuel with a higher aromatic and benzene concentration. In order to rectify this one of the following options can be introduced (IPIECA, 2003:8):

1. The purchase of high octane, low aromatic blend components such as MTBE and other oxygenates.
2. Capital investment in isomerisation units.
3. Investment in alkylation plants.
4. The introduction of MMT.

(IPIECA, 2003:9).

This basically entails that the plants either need to be upgraded or that new additives need to be introduced to the fuels.

In Mexico MTBE is currently added to fuel to enhance the octane value of local fuel. With the phasing out of this additive in the USA, there is a relatively high probability that it will be phased out there as well. Research has therefore been initiated to determine how the composition of the fuel can be altered. According to Lopez-Salinas *et al* (2004:177) this can be achieved with the addition of branched C_8 olefins. Their research concluded that the inclusion of C_8 olefins reduces CO and NO_x emissions. The only negative effect noted was in increase in formaldehyde emissions.

A point that is often overlooked is the decommissioning of the redundant lead alkyl facilities. These abandoned lead additive handling facilities can pose a potential health and environmental hazard if not closed down efficiently. The upgrade of refineries to meet new fuel specifications should therefore also include mitigation measures for plant closure (IPIECA, 2003:22).

3.4 South African phase out of leaded fuel and emerging vehicle emission legislation

In the early 1980's the Department of Mineral and Energy Affairs with the support of the Department of Health and Population Development started to reduce the lead content of fuel. With lead levels of fuel being lowered in developed countries, pressure was applied locally to introduce similar timetables for lead reduction (Von Schirnding, 1990:23). Between 1986 and 1989 the allowed lead level was reduced from 0.836g/litre to 0.4g/litre (Ellison *et al*, 1991:386). In 1994 the Department of Mineral and Energy Affairs initiated a vehicle emissions project. The first visible effect was the introduction of unleaded petrol in 1996 (Furlonger, 2002:69).

Different from other countries the initiative to phase out leaded fuel was driven very strongly from the vehicle manufacturing sector (Diab, 1999:118). Modern engine technology could not be introduced locally due to the high lead content of South African fuel. Pressure from this sector contributed to the reduction of the lead content of fuel and the introduction of unleaded fuel in 1996 (Diab, 1999:118). In 1998 the Minister of Transport stated that the introduction of unleaded fuel in South Africa was in fact motivated by technological and economic considerations and not primarily driven by environmental motivation (Department of Transport, 1998).

Lead particles are however only one part of a larger problem namely vehicle emissions. Theoretically the burning of a hydrocarbon fuel with air in a vehicle engine should produce carbon dioxide and water, while the rest of the exhaust emission should be nitrogen. Unfortunately the fuels that are used are comprised of hundreds of differently structured hydrocarbons which all burn in different ways and at different rates. These partially burned products react with each other to form a variety of exhaust emissions (Automobile Association, 2005).

The Department of Minerals and Energy together with the Department of Environmental Affairs and Tourism (DEAT) has since continued work on a Vehicle Emissions Strategy (VES) aimed at addressing the contribution of vehicle emissions to air quality. The VES was published in December 2003. According to the strategy the local problem with vehicle emissions has been increasing due to the rising number of vehicles and the increase in distances travelled (SA, 2003:4). The absence of vehicle emission legislation has also led to the current situation.

The strategy follows European guidelines and aims to introduce legislation in line with European emission standards in the next few years. It consists mainly of two parts:

1. The introduction of new fuel specifications.
2. The introduction of standards for vehicle emissions.

Apart from the above it will also entail the compulsory introduction of catalytic converters on all private and commercial vehicles over a phased period. Catalytic converters were first introduced in the United States in order to meet the requirements of their Clean Air Act (Octel, 2005). The proposed standards will prescribe limits on emissions such as carbon monoxide, lead and oxides of sulphur and nitrogen, the common exhaust pollutants (Furlonger, 2004b).

In comparison to developed countries, South Africa has been slower to react on the deteriorating quality of ambient air arising from vehicular emissions. Many of the vehicles on South African roads are old with outdated technology. They are often badly maintained and it is estimated that an average car emits as much as ten times the volume of exhaust emissions compared to equivalent European vehicles (SA, 2003:15). Most of the vehicles were also manufactured without emission control systems and those that have these systems are not monitored to ensure efficiency. The conventional fuels used locally contribute to the problem. Only 30% of local petrol fuels are unleaded fuel (Furlonger, 2004b).

According to the VES there are four role players in this program:

1. The government – responsible for the implementation of legislation and enforcement.
2. The fuel industry – responsible for the production of suitable fuels.
3. The vehicle manufacturers – responsible for the implementation of devices used to reduce exhaust emissions.
4. Vehicle owners – responsible for proper maintenance of vehicles to limit excessive emissions.

The VES outlines the challenges that may be faced. The first is fuel quality. The desired fuel should firstly not have any negative effect on emission control systems and vehicles. This entails that the additives should not damage engines or emission systems. Secondly the fuel should emit less harmful emissions, by eliminating substances such as lead, sulphur and benzene (SA, 2003:23).

According to *Engen* the production of high octane fuels without the conventional TEL can be achieved by the following (Mawson, 2004):

1. Making use of octane enhancing additives.
2. Blending with purchased high-octane blending components.
3. Refinery reconfiguration by means of capital investment.

The latter being the government's preference (SA, 2003:24). Table 1.2 outlines some of the proposed fuel specifications.

Table 1.2 Fuel Specifications for South Africa (SA, 2003:47)

Parameter	Unit	2003	2006	2008	2010+
Petrol					
Octane (coast)		97L 95/97ULP	91/95 ULP	91/95 ULP	91/95 ULP
Octane (inland)		93L 93 ULP	91/95 ULP	91/95 ULP	91/95 ULP
Aromatics	% v/v	42	42	42	tbd
Benzene	% v/v	3	3	3	tbd
Sulphur	ppm	500-800	500	500	50
Lead	g/l	0.4	0	0	0
Metal Additives (MMT)	ppm	18	*	*	*
Ethers and selected alcohols	mm	<10%ULP	2.7%	tbd	tbd
Diesel					
Sulphur	ppm	500	500	50	50

* Will depend on outcome of study
tbd – to be determined

According to Furlonger (2005:1) South African motorists generally believe that lower octane such as 91 is an inferior fuel. Although it is cheaper to produce and suitable for most vehicles, motorists may not want to use it because they simply do not trust the product.

To manage the regulation of vehicle emissions the VES is proposing that all new vehicles sold by a certain date will be fitted with emission control systems. By doing this there will be a definite increase in the percentage of vehicles fitted with these devices. An incentive scheme was considered to encourage vehicle owners to replace their vehicles with newer models, but this was found to be too costly. Although manufacturers guarantee their emission control devices for a certain period it is out of the manufacturers hands once sold. These devices therefore require regular testing and if malfunction is detected they have to be repaired and retested.

The VES propose regulations that will implement regular roadworthy testing that will include emission testing. It is thought that the Department of Transport would be responsible for the enforcement of the program through means of policies and legislation. The traffic departments will have to enforce the new standards through the licensing process (Department of Environmental Affairs and Tourism, 2003a).

The implementation schedule started in January 2005 with the compulsory fitting of emission control devices on all homologated passenger and light commercial vehicles. In January 2006 all newly manufactured vehicles will be affected. The program is scheduled to conclude in 2012 (SA, 2003:38).

The VES also outlines the economic impacts that can be expected. The first impact is the cost to vehicle manufacturers. The implementation of emission control systems will be costly and may result in an escalation of vehicle prices. The cost of implementing the new legislation is estimated to total more that R2.5 million by 2020. The cost or the reconfiguration of refineries is estimated at between R10 and R15 million. According to the VES the new legislation is however not expected to have a significant impact on the consumer due to the phased structure of the strategy (SA, 2003:44).

3.5 Sulphur in diesel

An aspect that has received somewhat less attention than lead is the sulphur level of diesel. Sulphur also has an adverse effect on human health. The exhausts of diesel vehicles emit particulate matter (PM) and noxious gasses including carbon monoxide, carbon dioxide, nitrous fumes and sulphur (Unsted, 2002:61). The formation of this PM can be lowered by 18 % with the reduction of sulphur from 3000ppm to 500ppm (SA, 2003:30). Sulphur dioxide is thought to contribute to health conditions such as asthma, emphysema and even cancer in association with soot. Sulphur is a problem for people with respiratory diseases and also contributes to photochemical smog (Gosling, 2002:2). The pollutants originating from diesel engines have further been associated with the cause of lung cancer and asthma attacks (Anon., 2000b:11).

Unlike lead, sulphur is a naturally occurring substance in diesel and not an additive (Anon., 2000a:12). As with the phase out of lead, the reduction in sulphur in diesel has been implemented worldwide. In the USA the level of sulphur was reduced to 300 ppm in January 2004 and will be reduced further to 15 ppm in June 2006. Canada had similar trends setting their standards at 150 ppm in 2002 and lowering it to 30 ppm in January 2005. The European Union has lowered their allowable sulphur level from 150 ppm in 2000 to 50 ppm in 2005 (Avidan *et al*, 2001:48). The UK lowered their levels from 2000 to 500 ppm in the 1990's and it is currently below 50 ppm.

In South Africa the maximum allowed sulphur level was decreased from 5500 ppm to 3000 ppm in 2002 (SAPIA, 2003:2). From January 2006 it will be lowered to 500 ppm. According to the VES it will be reduced to 50 ppm in 2008. *Sasol* is set to produce limited volumes of 50 ppm diesel prior to this date (Furlonger, 2005:2).

A major driving force for the phase out of sulphur is also the use of catalytic converters. The so-called storage type of catalytic converter reduces the nitrogen oxide emitted by diesel exhausts. The catalytic converter has a base coat consisting of barium or potassium oxide, together with platinum, palladium and rhodium. When nitrogen oxides come in contact with these metals it is converted to nitrates, which remain on the coating. At the point where the capacity of the catalytic converter is exhausted the engine management system changes some of the engine operating conditions. By this action the stored nitrates are converted to nitrogen and are released. The cycle then repeats itself, preventing harmful nitrogen oxides from escaping into the air and thus improving the air quality (Kimberley, 2001:18).

Sulphur hampers this process, since the sulphur deposits on the surface along with the nitrogen oxides. The sulphur reacts to form sulphates, which then permanently adheres to the surface, even through the regeneration process. As result of this the catalytic converter therefore loses 60 to 70% of its converting efficiency (Kimberley, 2001:19). The phasing in of catalytic converters would therefore have to be accompanied by the phasing out of sulphur in diesel. This follows the European trend of tightening emission control (Gosling, 2002b:1).

Apart form the environmental impact, the quality of South African diesel also has an impact on the motor vehicle industry. According to Hellberg (2004:3) the quality of South African diesel is not compatible with the newest technology available for diesel engines. Motor manufacturers are holding back the introduction of new technology in South African vehicles until the quality of the diesel improves. The sulphur content of diesel has been mentioned as a particular problem.

As with unleaded fuel the manufacturing of low sulphur diesel also requires refinery reconfiguration. Diesel is generally derived from the raw product of FCC naphtha and refiners are either treating the FCC feed or the FCC naphtha to achieve the new specifications. (Avidan *et al*, 2001:48):

Several South African diesel manufacturers have launched low sulphur products. *Caltex* are promoting their *Power Diesel* and *Sasol* their *turbodiesel* product. According to *Sasol* their product has the benefit of less engine wear and longer life; cleaner combustion and use will result in extended oil drains and service intervals (Sasol, 2004b:1).

3.6 South African air quality and relevant legislation

According to the State of Environment Report (SOER) for South Africa (Department of Environmental Affairs and Tourism, 1999:1), emissions from vehicles including aeroplanes, ships, trains and road vehicles are responsible for 44 % of the total nitric oxide emissions and 45 % of volatile organic compound (VOC) in ambient air. These substances are responsible for the formation of photochemical smog, especially in urban areas.

In a summary document on themes for the next SOER (Department of Environmental Affairs and Tourism, 2004:1), source emissions is listed as a priority issue to be analysed for the 2005 national SOER.

In September 2000 two experts on the field of air quality visited South Africa. They were Dr. James Lents and Richard Nikkila from *Global Sustainable System research* (GSSR), a US environmental consultant group. They were invited by the Refinery Manager's Environmental forum of South Africa (RMEF) to meet with environmental non-governmental organisations, environmental officials from the government and representatives from the local petroleum industries. The aim of the visit was to assess the South African pollution control measures and suggest an action plan for the future (Lents & Nikkila, 2000:1). Their findings were listed in two sections namely an assessment of SA's air pollution management system and secondly an evaluation of SA's oil refineries' air pollution reduction activities.

Regarding the air pollution management the report found that South Africa is generally in a period of social and political change that caused environmental management to fall behind. South Africa then was in a very similar position to the US in the 1970's with few air quality standards, including monitoring and emission inventories. South Africa however has the advantage that the country is in a position to learn form other countries' experience. On vehicle emissions the country was particularly lacking sufficient emission control and this was highlighted as one of the opportunities for improvement.

Home fires were identified as one of the largest environmental threats to public health. Since the majority of households, without access to electricity, use coal for cooking and heating inside their homes, these emissions are a significant threat to the health of the general population.

It was concluded that although attention is urgently required for air quality improvement it would not be successful without the implementation of environmental sustainability programs. It was emphasised that in order to implement an air quality program, substantial resources would have to be made available.

On the existing air pollution reduction activities of local refineries the report mentioned that the industries are moving in the right direction. Emission inventories were being used although not at all refineries. There was room for improvement especially in introducing emission reduction measures. National ambient air quality standards needed to be introduced, based on the capacity in the various areas, inventory of emissions and economical feasibility.

(Lents & Nikkila, 2000:3).

The vehicle emission strategy (VES) as discussed earlier can not be viewed in isolation. It is very closely related to the national air quality legislation. This legislation is currently being updated.

Up to now South African air legislation is governed by the Air Pollution Prevention Act of 1965 (APPA). This Act has inadequate compliance and enforcement mechanisms. The legislation is relatively outdated and subsequently a new Air Quality Bill was published in 2004 and the Air Quality Act (39/2004) was promulgated in February 2005. This Act has not yet been implemented. The intention of the new legislation was to reform the law regulating air quality in order to protect the environment. It is expected that once the Act comes into effect, it will introduce stricter regulations which will be able to provide for better air quality management.

The new legislation provides for the identification of listed activities and controlled emitters that would be governed by the Act (39/2004). The metropolitan and district municipalities will be responsible for the implementation of a new atmospheric emission licensing system. This includes applications, decision making and issuing of atmospheric emission licences. There are however concerns about the ability of the municipalities to enforce this legislation.

The Act aims to establish ambient air quality standards for the respective regions in the country. The following air pollutants are targeted:

- Ozone (O_3)
- Oxides of nitrogen (NO_x)
- Nitrogen dioxide (NO_2)
- Sulphur dioxide (SO_2)
- Lead
- Benzene
- Particulate matter (PM)

Together with the Act two standards were drafted by Standards South Africa. The first, SANS 1929, provides guidelines for the limits for pollutants and also provides details regarding sampling points for the measurement of atmospheric pollutants (Standards South Africa, 2004a:5).

The second, SANS 69, describes a framework for the implementation of the set standards. It defines the basic principles of the strategy proposed for ambient air quality management in South Africa (Standards South Africa, 2004b:3). According to Kornelius (Anon., 2004:31) the publication of these standards is the beginning of a process where the focus will change from air quality management to the management of ambient air quality.

None of these documents mention the regulation of point source emissions. The framework only refers to ambient pollutant levels. Chapter four of the Act does mention controlled emitters, but there is no specific reference to vehicle emissions and their contribution to ambient air quality. Further detail will probably only be available once regulations are published. The Act will only come into effect on a date proclaimed by the Minister of Environmental Affairs and Tourism.

3.7 Alternatives fuels and additives

The move towards the introduction of cleaner fuels requires two important characteristics from these new fuels. In the first place the use thereof should result in less harmful emissions whether the vehicle using it is fitted with emission control devices or not. Secondly the fuel must be compatible with emission control systems and not have any negative impact on them (SA, 2003:23).

With the elimination of lead from petrol an alternative additive is required to boost octane and therefore prevent engine knock. Engine knock can be described as the uncontrolled combustion of the last part of the fuel and air mixture in the combustion chamber of a vehicle's engine. This knock effect can reduce power, engine efficiency and increase the heat load on a vehicle's cooling system (IPIECA, 2003:7). The octane rating of a fuel is very important for the efficiency of the latest vehicle technologies. This includes closed loop ignition control, supercharging and turbo charging (SA, 2003:24). Apart from this the additive must further be able to prevent valve seat, one of the properties that made the use of lead so attractive in the first place.

According to the SA government, the largest challenge posed by the phase out of leaded fuel is the identification of a suitable alternative additive that will not have a detrimental effect on human health or the environment (SA, 2003:8). The natural concern is that an alternative introduced may prove to pose unknown hazards to man, which could only be discovered later. Almost all new additives brought to the table have undergone criticism to some extent.

The addition of alternative heavy metals has been heavily criticised. In October 2003 dr Crispian Olver, the then Director-General in the Department of Environmental Affairs and Tourism, stated that in the light of insufficient knowledge of the safety of these additives, their use is discouraged (Department of Environmental Affairs and Tourism, 2003b:1).

The most common way to replace lead is by adding more aromatics. This results in increasing the aromatic component of petrol from 20 to 40%. Aromatics are however not particularly environmentally friendly (Clancy, 2001:30).

As early as 1923 (Kitman, 2000), ethanol was discovered to be a suitable alternative to lead, but as mentioned it could not be patented and lead was promulgated as the suitable alternative. With the out-phasing of lead the search for a suitable alternative is a controversial topic. A discussion on some of the additives is given below:

3.7.1 Methyl Tertiary Butyl Ether (MTBE)

Methyl tertiary butyl ether (MTBE) is a so-called fuel oxygenate. It is a colourless, volatile liquid highly soluble in water (Wilkes University, 1998). According to the USA Environmental Protection Agency (EPA) it is classified as an animal carcinogen with the potential to cause cancer in humans.

MTBE is generally produced by the reaction of methanol with isobutylene (List, 1986:32). It is a widely known octane booster for unleaded fuels and has been used since the 1970's. With the initial phase out of lead, MTBE seemed to be a very suitable alternative octane booster. MTBE adds oxygen to the fuel, which increases the temperature at which it burns, resulting in a reduction of by-product formation in a vehicle's exhaust system (Wilkes University, 1998:2).

It was however soon discovered that this additive was polluting aquifers. MTBE is miscible with water and can therefore easily cause groundwater contamination. The most common source of contamination is leaking underground storage tanks, piping and pumps used in the filling process (Faloon, 2004:9). The MTBE leaches out of the fuel and since it is much more soluble than any other component in fuel, dissolves in the water (Burdick & Leffler, 2001:85). MTBE vapours coming in contact with water will also dissolve readily. To make matters worse it is very slow to biodegrade. The cost associated with the clean-up of contaminated water supplies is also significant (Preston, 2004:28).

Although it may cause water pollution, it does not pose a direct risk to human health. It is currently not known at what concentration level MTBE in water becomes a health hazard to humans (Faloon, 2004:9).

The United States Senate added amendments to their Energy Bill in June 2003 calling for the phase out of MTBE (Geiselman, 2003:15). Several sources believe that that the MTBE industry was aware of the water contamination potential, but nevertheless encouraged its use. In the USA a heavy debate is currently ongoing on liability issues surrounding pending rehabilitation costs (Preston, 2004:28).

In the relative short period that MTBE has been in use it contributed considerably to the improvement of quality of air. On the other hand in many areas were the additive is used MTBE levels of storm water run-off and underground water has increased significantly.

One problem was simply replaced with another and this clearly illustrates that the identification of a suitable alternative additive is not as simple as might be expected.

3.7.2 Methylcyclopentadienyl Manganese Tricarbonyl (MMT)

With the commencement of lead phase out in the 1970's, one of the first alternatives used was methylcyclopentadienyl manganese tricarbonyl (MMT). In Canada it was used from 1976 since it was an alternative that could boost the octane rating of fuel ensuring clean fuel burning without damage to engines. It also reduces emissions from automobiles, primarily emissions of nitrogen oxides, therefore reducing urban smog (The American Council on Science and Health, 1998). From the 1990's there was however some growing uncertainty regarding the toxicity of manganese and the extent of human exposure due to emissions from vehicles. Vehicle manufacturers also claimed that MMT is harmful to emission control systems (Sissell, 1997:34).

MMT contains manganese, which is a heavy metal like lead, but with entirely different characteristics. When lead is added to fuel the concentration of lead is approximately 400mg/l while the use of MMT results in only 18 mg/l of manganese. In comparison this would result in 80 tons of manganese added to petrol instead of 4500 tons of lead, should MMT be used for all fuel in South Africa (Clancy, 2001:30).

When MMT is combusted it burns to form manganese and a variety of carbon compounds including carbon monoxide and hydrocarbons. Some of these compounds has proved to be toxic in high concentrations, and are suspected to have an impact on health even at low concentrations, especially if inhaled.

Manganese at low concentrations is however a natural essential part of the human diet (National Round Table on the Environment and the Economy, 2003). Manganese is an essential nutrient for the human body. It is required for protein and energy metabolism, metabolic regulation and cellular protection from free radicals. According to Van Niekerk & Fourie (2003:5) the greatest public exposure to manganese is usually from food. Manganese occurs naturally in soil, air and water and therefore also in food. Humans are exposed to the metal on a daily basis. The exposure through water is lower than from food, and exposure to manganese from air is even lower (Van Niekerk & Fourie, 2003:5).

Studies done in Canada where the additive has been in use for twenty years have shown no significant increase in environmental manganese levels. Even individuals that are exposed to a higher than average amount of exhaust emission such as taxi drivers have shown no adverse effects (The American Council on Science and Health, 1998).

Despite this there has still been huge controversy surrounding the use of MMT. It has been the subject of numerous studies and enquiries in a variety of countries. The grounds for this controversy are the fact that manganese is a neurotoxin, which can potentially cause irreversible neurological disease if inhaled in large quantities (Environmental Protection Agency, 2003).

According to Solomon (1996) the fact that adults are generally not affected by manganese exposure through ingestion, are not enough to prove that it is not potentially harmful. Normal healthy adults are able to excrete excess amounts of manganese without trouble. It is however people with iron deficiency, foetuses and infants that could be at risk. This group absorbs the metal much more avidly and are not able to excrete excess amounts. Early exposure may also not show adverse affects right away. Inhaled manganese also differs from manganese which is ingested. It is absorbed through the lungs, is excreted less easily and can therefore accumulate in the body.

At high doses manganese can cause severe damage to the neurological system, known as manganism. The symptoms are very similar to that of Parkinson's disease. It is also proven that high doses can affect the reproductive system (Solomon, 1996).

Studies have shown that the levels of manganese will not increase significantly as result of its use in fuel. One has to keep in mind that the normal levels of manganese are low. Over an extended period the constant deposit of small amounts of manganese could accumulate in soil. This could potentially result in increased manganese levels in living organisms. According to Solomon (1996) it could accumulate in certain plants, which could eventually then spread to humans. It is therefore clear the long-term effects of manganese are yet to be proven.

The United States EPA has been actively involved in the ongoing investigation of the potential health affects of MMT. They have made several attempts to have it banned, but in the light of inconclusive scientific results have reluctantly approved the use of MMT. The EPA has however insisted on ongoing testing required from the Ethyl Co-corporation, the manufacturer of MMT. The results of this longer term test work will hopefully provide more conclusive results (The American Council on Science and Health, 1998).

Despite these concerns the use of MMT has spread worldwide. It is currently being used in the USA, Canada, France, Italy and the United Kingdom. It was introduced to petrol in South Africa by *Sasol Oil* in 2001 (Van Niekerk & Fourie, 2003:1). *Sasol Oil* consulted various government departments, vehicle manufacturers and the Automobile Association (AA) before introducing the additive. They embarked on a voluntary health risk study to investigate whether MMT would have any effects before release of the product (Clancy, 2001:30). They have also conducted extensive tests with test vehicles, proving that the additive has no negative effect on the exhaust system of both older and newly manufactured motor vehicles.

Despite this effort, local motor vehicle manufacturers have objected to the use of manganese containing additives, claiming that it has a negative effect on emission control devices and on-board diagnostic systems (SA, 2003:26). It has also been claimed that MMT contributes to blockages in catalytic converter systems. According to tests done by a variety of motor vehicle manufactures including *BMW, Nissan, Saab, Volkswagen* and *Delta Motor Company*, it was found that the manganese in unleaded fuel is responsible for the clogging of catalytic converters (Gosling, 2003:1). Catalytic converters damaged as result of manganese build up can cost up to ten thousand rand to replace.

The Worldwide Fuel Charter claims that MMT coats internal engine devices, causing misfiring of sparkplugs, which can lead to an increase in emissions en poor engine performance (Anon., 2001:17).

Internationally many tests programmes have been conducted to investigate these allegations. Most of these tests conclude that emissions of hydrocarbons increase while NO_x emissions decrease with the use of MMT. Also catalyst conversion efficiency improved but the overall engine–out emissions seemed to increase. In one report issued in 2002 the conclusion is made that fuel with MMT is not suitable in the most sophisticated emission systems if very low emission levels are required. It is however suitable for older emission technology vehicles if the use of MMT can contribute to the phase out of leaded fuel (IPIECA, 2004:17). It seems to be considered as a better option compared to lead but still not the ideal additive.

The National Association of Automobile manufactures of South Africa (NAAMSA) have also expressed their concerns with the introduction of MMT. They endorse the use of metal additive free unleaded petrol because its modern technology catalytic vehicles performs better with fuels free of metal additives.

Locally *Sasol, Petro SA, Total* and *Engen* add MMT to their fuel. *Shell* and *Caltex* do not add the additive, but do sell it because of fuel purchase agreements (Gosling, 2003:1).

The South African government is currently considering the addition of a levy on the use of MMT in petrol. These funds would be utilised for the funding of research on the environmental impact of the additive, should the need arise in the future (SA, 2003:11). From 2006 it will only be allowed in lead replacement fuels, and prohibited in unleaded fuel (SA, 2003: 10).

3.7.3 Potassium

Although potassium has some valve seat protection characteristics, it does not have any significant octane boosting properties, making it unlikely to be a suitable alternative (SA, 2003:26). It may however be used in lead replacement petrol, and some companies have been using it, claiming it to be better than MMT.

3.7.4 Ethanol

Locally there has been much talk about the production of bio-ethanol through the agricultural sector utilising maize, soybeans and sugarcane. In is particularly the maize industry that will benefit from this new endeavour. Currently South Africa has a surplus of three million tons of maize, which could potentially increase to seven million toward the end of the year (Duvenhage, 2005:4). The potential use of this surplus to produce ethanol is therefore very attractive to the agricultural sector.

Ethanol Africa, the company which was founded to produce ethanol from maize, is planning to start production of ethanol as soon as 2006 (Janse van Vuuren, 2005:19). Eight new plants with a total annual production capacity of 1.26 million litres are currently being planned.

There has however been some scepticism from the agricultural sector regarding the potential negative impact of this venture on other agricultural sectors such as the sunflower and soybean industries. The issue is the overproduction of by-products from the ethanol production facilities. This may even threaten the economic viability of the bio-fuel industry if not considered carefully (Van Burick, 2005b:76).

Internationally ethanol has been added to fuel for quite some time. It can be used to boost the octane level of fuel. Up to 8% can be added to petrol without requiring any changes to conventional motor vehicle engines (Van Burick, 2005a:74). The benefits of bio-fuel are that it does not contain any sulphur, and the fact that it results in less CO_2 and carbohydrate emissions. Worldwide the development of renewable energy sources is gaining support. Brazil is considered to be the world leader in the production of ethanol for fuel, with 25% of its fuel market utilising ethanol (Harris, 2005:25). The European Union is currently aiming to blend 2% of bio-fuel into their conventional fuel pools and to increase this percentage to 20% by 2020.

Sasol is currently investigating the viability of producing bio-diesel from soybeans. This will be blended into the existing diesel pool. A production capacity of 100 million litres per annum is currently being considered. An estimated 475 000 tons of soybeans will be required. If the proposed project goes ahead, production will probably commence in 2007 (Van Burick, 2005a:74).

The addition of ethanol to fuel has the disadvantage that it biodegrades very rapidly. This is a disadvantage because all the other substances in fuel biodegrade much slower. This results in the plume of these other substances spreading more rapidly (Fiorenza *et al*, 2002:779). In the case of a spill or leak of fuel the addition of ethanol has a detrimental effect even though it does not cause contamination of its own. The additive will therefore also have environmental impacts despite the fact that it can be manufactured from renewable sources.

4. Discussion

4.1 Impact on the fuel industry

The proposed new fuel specifications will have a significant financial impact on the fuel manufacturers of South Africa. Most companies have been producing unleaded fuel for a few years. Apart from manufacturing unleaded fuel the large number of older vehicles on the South African roads have also created the need for the production of lead replacement fuel (LRF) (Anon., 2004c:2). These fuels require alternative metal additives that are less harmful than lead, including potassium, manganese and iron. The refinery industry has asked the South African government for funding to ease the financial burden of the required refinery transformations but to date no assistance has materialised.

In South Africa the respective fuel companies have embarked on the process of producing so-called cleaner fuels since the late nineteen nineties. The introduction of *BP Cleaner diesel* was initiated in KwaZulu-Natal in May 2000. *BP* launched their new unleaded petrol at all their service stations on 13 August 2000. Their product also contains additives that enhance the performance of vehicles by containing combustion improvers that reduce black smoke (BP, 2000b:1).

According to *BP* (2000a:1) they are opposed to the use of manganese-based additives in petrol due to the uncertainty of the effect that it may have on the human health and the environment. Part of their market strategy is also to promote the fact that their fuel is "heavy metal free". BP has also recently opened their first service centre in the Western Cape selling exclusively unleaded fuel. The company spent R20 million to upgrade their refinery in Durban (Williams, 2004:1). According to *BP* their fuel is the only heavy metal free fuel available countrywide at present.

Engen has introduced its unleaded fuel as *Dynamic Unleaded*, a fuel that is also suited for older vehicles specifically requiring leaded fuel. It is claimed that this fuel reduces exhaust emissions (Engen, 2004:1). The company plans to spend between R400 million and R500 million on the changes required to produce the new specification fuels (Anon., 2004f). A further investment of R2 billion is planned for 2010 when even stricter sulphur level legislation will come into effect (Mawson, 2004).

Vortex unleaded is the *Caltex* product produced to replace leaded fuel. Different from most of the fuel manufacturer's products *Vortex unleaded* is not suitable for use in all older cars, previously using leaded fuel (Caltex, 2003a:1).

Sasol launched their *dualfuel* product in 2002. This product was developed for use in vehicles requiring either leaded or unleaded petrol. According to *Sasol*, it is the only petrol in South Africa guaranteed for use in all petrol engine vehicles regardless of age and technology. This product reduces potentially harmful airborne metal emissions, caused by conventional leaded fuel (Sasol, 2004a:1). Other claimed benefits include cleaner fuel inlet systems, longer exhaust life and longer spark plug life.

Sasol introduced their *turbodiesel* product in February 2002 (Sasol, 2004b:1). This product reduces harmful exhaust emissions such as sulphur dioxide and sulphate particles due to it low sulphur content.

All fuel producing companies had to review their current production processes in order to meet the new fuel specifications planned for 2006. The course of modifying a facility in order to produce a product that meets the new specifications is complex and also very costly. According to West (2002:11) local oil refiners will have to spend about $1 billion up until January 2006 to comply with the new regulations.

According to Larbey (2004:15), an international consultant in fuel and fuel additives, the time period provided locally for these refinery conversions is too short. The high capital cost associated with the conversions should ideally be spread over a longer time period. Internationally refineries in countries such as the United States, Canada and Australia were given periods of up to twenty years for the transition. This eases the financial impact significantly.

In 2002 *Sasol* embarked on the so-called Project Turbo, the combined name for the series of projects required to implement technology changes in order to meet the new fuel criteria. *Engen* has also announced its commitment to this change in the press (Kloppers, 2003:5).

For the purpose of this dissertation the impact on three factories will be discussed briefly as examples. They are the two *Sasol* factories in Sasolburg and Secunda and the *Natref* refinery in Sasolburg.

4.1.1 Sasol – Secunda

The current operation facilities in Secunda produce large volumes of fuel. The new fuel legislation left the industry no choice, but to modify their existing production facilities in order to meet the new specifications. The project required a substantial capital investment. Different from other projects, there would be no additional product sold or revenue generated, which would therefore present a potential loss in revenue for the company. In order to compensate for this situation, *Sasol* introduced additional changes linked to the required modifications in order to generate additional revenue (O'Beirne & Boer, 2003:7).

An Environmental Impact Assessment (EIA) was required before this project could go ahead. This assessment investigated what the impact of the project would be on both the physical and social environment. The specialist studies conducted covered a variety of fields including air emissions, liquid effluent handling, solid waste disposal, energy consumption and social impacts (O'Beirne & Boer, 2003:9).

According to O'Beirne & Boer (2003:39) emissions, liquid effluent and solid waste creation impacts were determined to be of low significance. Since more water would be required this would put strain on the already low water availability in the area and its impact significance was therefore rated as high.

On the social front mixed predictions were made. Of high significance would be the increased workforce with associated increased occupational health and safety risks. The influx of workers to the existing community also predicted medium significant impacts in the form of increased socially disruptive behaviour; conflicts with locals; threat of spread of sexually transmitted deceases and potential labour disputes. On the positive side the project would create additional temporary employment; increased household income and a general increase in economic activity (O'Beirne & Boer, 2003:50).

Authorisation was granted by the Mpumalanga provincial authorities and construction is currently under way. According to Furlonger (2005:1) the plant will be ready for operation in December 2005 and fully operational three months later. It is expected that *Sasol* may have to import additional unleaded fuel to meet the initial local demand.

4.1.2 Natref

The *Natref* refinery in Sasolburg manufactures a variety of fuels from crude oil including petrol, diesel and jet fuel. The refinery is jointly owned by *Sasol Oil (Pty) Ltd* and *Total South Africa*.

In 2003 *Natref* embarked on the Natref Clean Fuels project in response to the changed fuel specifications. The project aimed to reduce the sulphur dioxide, lead and volatile organic content of their products (Watson *et al*, 2003:1-1). The project entails the modification of a variety of manufacturing equipment on the existing plant (Sunil, 2003).

An Environmental Impact Assessment (EIA) was required in order for the project to commence. The main impact as concluded by the assessment was an improvement of ambient air quality as result of the implementation. According to Watson (2003:7-2) the air study performed during the EIA indicated that a 24% reduction in sulphur dioxide emissions from the plant could be expected upon implementation. The sulphur dioxide emissions from vehicle activity are further expected to drop by 74.4% as result of the use of low sulphur fuel. Other positive impacts included the creation of temporary jobs during construction, and improved health due to the lack of lead emissions from vehicles (Sunil, 2003).

Authorisation was granted by the Free State Department of Tourism, Environmental and Economic Affairs (FS-DTEEA) in March 2004. Construction commenced toward the end of 2004 and is currently ongoing.

4.1.3 Sasol - Sasolburg

As result of the changes to the Secunda fuel production facilities an excess amount of ethylene will be produced at these facilities in future. *Sasol* considered various alternative uses for this additional feedstock material and it was decided to use the ethylene to produce additional polyethylene at the Sasol Midland site in Sasolburg. The ethylene will be transported to Sasolburg by pipeline (Sewmohan, 2003:3).

Sasol Polymers currently uses ethylene to produce polyethylene in two plants on the Midland site, Polythene 1 and Polythene 2. *Sasol Polymers* will expand their current production capacity by increasing the capacity of the current plant and the construction of a third new Polythene 3 plant.

The EIA conducted for these modifications and the new plant revealed no major significant impacts (Sewmohan, 2003:37). The technology used can be considered a relatively clean with very little effluent production. Again the positive impacts included temporary employment creation with associated economic activities. The air study conducted concluded that the impact on the air quality was of low significance and that all air emissions would be within the current air quality guidelines (Watson, 2003:7-2). Authorisation was granted by FS-DTEEA in October 2003. Construction commenced in November 2003 and completion is planned for October 2005.

Apart from the cost of the physical reconfigurations industries also have to carry the cost of the EIA's performed. From an environmental point of view most of these refinery changes do not seem to have any significant impact.

According to a survey done in May 2004 by the Sunday Times, oil companies seem to be on track to meet the deadline for new fuel specifications. Some of the companies may however have to import fuel for a short period of time if the required conversions are not completed in time. As mentioned, capital investment for these changes is significant and a proposal for the government to provide companies with some form of incentive is currently under consideration (Anon., 2004f).

4.2 Impact on motor vehicles

The South African out-phasing process started with the reduction in the concentration of lead in fuel in the early 1980's and culminated with the introduction of unleaded fuel in 1996. Even though the cost of this fuel was lower than the traditional leaded counterpart, it still had won only 30% of the market share at the start of 2001. This could be due to the fact that the rate of vehicle replacement is slow (Furlonger, 2002:69). Older vehicles need the lead in the fuel as lubrication for their valves and cannot run efficiently for extended periods on unleaded fuel. Since May 2000 new cars had been fitted with smaller fuel-inlet pipes that could not accommodate the larger nozzle of the leaded fuel pumps (Gosling, 2002:2). Despite these changes unleaded fuel is still not widely used.

According to a survey performed by *Shell V-Power*, 80% of South Africans still use leaded fuel. This can mainly be attributed to misconceptions about unleaded fuel. According to Mathlethle Mosetihi, marketing manager of *Shell V-Power*, motorists are generally not sure which cars are suited for unleaded fuel (Anon., 2003:21).

There are also many questions regarding engine protection and fuel economy (Anon., 2003:21). The initial resistance of motorists to use unleaded fuel can further be attributed to the fact that lower performance from vehicles has been experienced in the inland areas due to the initial lower octane of unleaded fuel compared to leaded fuel. From 2000, the introduction of higher-octane fuel has contributed to the increase of the market penetration (BP, 2000c:1).

The Cape Town Metropolitan Council (CMC) launched a diesel vehicle emission program in 1999. Reports have shown that the growing air pollution problem is mainly as result of diesel-powered vehicles (CMC, 1999:1). The program involved the random checking of vehicles using a roadside smoke emission testing apparatus, the Hartridge meter.

From 2006 it will be compulsory for all newly manufactured vehicles to be fitted with catalytic converters. This is required in order to meet the original European emission standard known as Euro 1. It will ensure that fewer pollutants such as carbon monoxide, SO_x and NO_x emissions are emitted (Furlonger, 2004:1). As outlined by the Vehicle Emissions Strategy (VES) stricter emission standards will also be implemented in the near future. This poses a problem for older vehicles, since installing new technology on these vehicles can be extremely expensive (Furlonger, 2003:1). It is also not yet clear how these vehicles will be penalised should they not comply with the emission standards.

As result of this the manufacture of automobile emission control systems is globally one of the fastest growing industries. Locally more than 10 million units are produced per year, many of which are intended for the foreign market (SASSDA, 2005:1). The South African industry currently supplies 10% of the world market.

Many older vehicles are not compatible with unleaded fuel and lead replacement fuel (LRF) has therefore been introduced. It is however expected that these fuels will only be available for a limited period (Furlonger, 2004). According to Manny Singh, the spokesperson for The Department of Minerals and Energy, 97% of South African vehicles could run on unleaded fuel (Anon., 2004d:12). According to Singh motorists concerned about valve seat damage would be able to buy separate additives that could be added to their fuel.

The new legislation will further affect the price of the current budget vehicles. Many of these still use carburettor engines, which are not so compatible with catalytic converters (Furlonger, 2003:1). They will therefore either become very expensive due to upgrades or will disappear from the market completely. Vehicles such as the *Toyota Tazz* and the *VW Golf 1* are likely to be removed from the market by 2008 (Furlonger, 2005:2).

On the positive side catalytic converters are able to eliminate 90% of the harmful substances in exhaust emissions (Kloppers, 2003:5). Other benefits include lower service cost, longer intervals between oils changes, increased fuel economy and extended spark plug life (Anon., 2003:21).

Further good news is that most of the South African heavy vehicle market is emission compliant. Many of these vehicles are imported and therefore originate from markets where stricter emission standards have already been introduced (Furlonger, 2004:1).

The need for change in South Africa is not purely environmental. Currently many of the newly manufactured vehicles available in the country are designed for clean fuels and catalytic converters and therefore not for the older fuels available in South Africa (Furlonger, 2004:1). Especially diesel vehicles need more regular services due to the quality of South African diesel.

The export market also requires the phase out. It is becoming increasingly important that internationally accepted emission and engine standards are followed. Large manufacturing companies such as *Toyota* and *BMW* can no longer afford to support duel systems (Furlonger, 2004:1).

The average local motor vehicle owner will therefore be obliged to use either unleaded fuel of LRF in the near future. The cumulative financial impacts of the associated changes is however still unknown. It is also expected that there will be quite some dissatisfaction from motor vehicle owners regarding the proposed octane levels of the new fuels.

4.3 Implementation of vehicle emission legislation in South Africa

The need for the change to cleaner fuels and the motivation for the vehicle emission strategy are warranted. It will definitely benefit human health and the environment if this strategy is followed. The manner in which it is implemented is however the important factor.

According to the IPIECA (2004:10) there is no magic solution to the phase out of leaded fuel. A lead phase out program should take into consideration the following:

1. The reason for the phase out (whether environmentally or technology driven etc.).
2. Regional vehicle requirements.
3. Existing refinery capacity.
4. Resources to manage the transition.
5. The need for lead replacement fuel.

According to IPIECA (2004:9) each country's situation is unique and great care should be taken that the phase out is workable under local circumstances. In South Africa it is therefore very important that the country's unique circumstances be taken into account with the phase out of leaded fuel.

In Mexico, three programs were followed to reduce vehicle emissions in the area of Mexico City. The first focussed on setting standards for vehicle emissions, focusing on newly manufactured vehicles from 1975, followed by more stringent standards in following years (Schifter *et al*, 2004:2065).

The second initiative was the implementation of an inspection and maintenance program in 1988. It entailed a mandatory emission test on all gasoline vehicles on a six-monthly basis. This ensured that vehicles not complying were either repaired or removed from the road (Schifter *et al*, 2004:2065).

The third program involved the improvement of fuel (Schifter *et al*, 2004:2066). Fuel specifications were based on composition and limits were set for benzene, total aromatics, olefin volatility and sulphur.

According Fowler (2004:9) the UK will not be able to meet their emission targets set for 2008. Although the average emissions of vehicles have decreased significantly from 1995 the current rate of reduction is not sufficient. In order to meet the set standards, the UK would have to double the annual reductions reached up to now. The cost of emission reducing technology is further increasing and the European Car Maker's Association are planning to suggest to the European commission to consider a wider range of factors when setting new emission targets (Fowler, 2004:9).

According to Larbey (2004:15), a UK based international consultant on fuel and fuel additives, the time frame given locally for the phase out is too short. In countries such as the Australia and Canada the transition took between fifteen and twenty years to complete. In the USA the first unleaded fuel was introduced in 1974 with the complete phase out only coming into affect in 1995. In South Africa the time frame from first introduction to total phase out is currently ten years, which is significantly shorter in comparison.

The introduction of new technology catalytic converters is one of the large drivers for the phase out of leaded fuel. As mentioned these devices are not compatible with leaded fuel. With the elimination of lead, additional additives such as aromatics and oxygenates have to be added to the fuel to enhance the octane number. The new fuels therefore create more aldehydes, oxides of nitrogen and benzene emissions. This is not a problem when a vehicle is fitted with a catalytic converter, since these toxins are destroyed. The problem however arises when vehicles that are not fitted with catalytic converters start using these new fuels. Although a so-called "cleaner" fuel is used it can result in even more harmful emissions being emitted. According to Larbey (2004:15) it is therefore preferable that the conventional fuel is available for a longer time to accommodate older vehicles.

From both a health and environmental view this is a sound motivation to rather delay the total phase out of leaded fuel. If older vehicles are forced to use new fuels it may have a significant adverse effect on the air quality, especially in urban areas.

In Mexico City the reduction of lead in fuel caused an increase in smog, directly related to the increased exhaust emissions due to the higher aromatic content of the new fuel (Larbey, 2004:15). The unleaded fuel may further pose a risk to alternative uses of the product. Equipment using petrol such as lawnmowers and chain saws are not fitted with catalytic converters and people working with these machines may be at risk of being exposed to harmful emissions not present in conventional fuels (Anon., 2004e:1).

In South Africa it is estimated that less than 10% of the vehicles are fitted with catalytic converters. According toe the *Automobile Association* (2005:1) vehicle emissions are influenced by the following factors:

- Fuel type.
- The age of the vehicle.
- Fuel quality.
- The quality of maintenance of the vehicle.
- How the vehicle is used (urban vs. suburban driving).

Although the VES plans to make the implementation of catalytic converters compulsory for new vehicles the vast majority of vehicles on the South African roads will not be fitted with these devices. According to Larbey (2004:15) the penetration of catalytic converters is likely to only reach 50% by 2010. This is four years after the phase out of leaded fuel.

Although atmospheric lead is a health risk as discussed, the concentrations of lead in the local ambient air is currently below the international safety levels. This can be attributed to the fact that compared to other countries; South Africa has a relatively small vehicle fleet. Larbey (2004:15) concludes that the phase out of leaded fuel should be postponed in order to allow for the introduction of a larger percentage of catalytic converters.

Stuart Rayner from the National Association of Automobile Manufacturers of SA (NAAMSA) commented on the suggestions made by Larbey. According to him 70% of vehicles manufactured in South Africa are fitted with catalytic converters. He mentioned that the prevalence of leaded fuel may cause motorists to use the wrong fuels. He also stated that limits would be set for the levels of benzene and other additives (Rayner, 2004:8). He did not make any reference to the composition of the South African vehicle fleet and the problems related to older vehicles using new fuels.

Currently the plan is that lead replacement fuel (LRF) will be available in South Africa until 2010 after which additives will be sold separately (Friedland, 2004:26).

The VES set out in December 2003 proposes the introduction of vehicle emission testing. This in itself is not a bad suggestion. It will however be challenging to administrate this in South Africa. The country is currently struggling to manage roadworthiness of vehicles. If this problem can't be properly managed it is doubtful whether the current system will be able to handle the additional load of vehicle emission testing and related law enforcement.

Apart from private and commercial vehicles the majority of construction vehicles also use diesel. This sector contributes significantly to air pollution and it is important that these non-road vehicles are also regulated (Anon., 2000b:11).

The vehicle emission standards were originally set to be implemented in 2004, but the setting of the final standards and issues surrounding the enforcement of them are currently delaying implementation.

4.4 Emission management and control options

There are several technologies available to control emissions efficiently. One alternative is to introduce on board diagnostic (OBD) testing. Internationally the use of this form of emission testing has been implemented to monitor vehicle emissions. The purpose of the OBD system is to ensure that the emission control system of a vehicle is functioning properly.

Since the 1980's many vehicles have been fitted with on-board computers to direct the engine control systems. This represented a move from mechanical systems to be replaced by electronic systems. The so-called on board computer monitors the function of the vehicle by mean of sensors and actuators. Any malfunction can be detected before the driver of the vehicle becomes aware of the problem. These sensors together with the diagnostic software make up the so-called OBD system (Illinois Environmental Protection Agency, 2004).

Together with the normal vehicle function monitoring new OBD systems have been developed that can also identify problems with the emission control system of a vehicle. Problems can therefore be detected much earlier than with exhaust emission tests. This allows time for the emission control systems to be repaired prior to the vehicle becoming an excessive polluter (Illinois Environmental Protection Agency, 2004). As with other malfunctions of the vehicle the problem is communicated to the driver by means of a light on the dashboard exclusively for emission problems.

With these systems installed testing officers can verify the emission control system by attaching a cable to the on board connection whereby the OBD systems status can be tested.

In addition to the control of emissions these systems have many other consumer benefits. They are able to detect vehicle deficiencies at an early stage, preventing expensive repairs at a later stage. In the state of New Hampshire in the United States mandatory implementation is currently being put into practice (Nolin, 2004:11A). Even there, there have been some difficulties with the implementation process. Apart from the fact that these systems have to be installed they must also be inspected by professionals at regular intervals. OBD inspectors have to be trained and inspection stations have to be set up. It can only be expected that similar problems will be experienced locally should it be implemented.

Apart from vehicle exhaust emissions, emissions from fuel tanks are also receiving attention internationally. In California legislation governing vapours escaping from tanks is currently being contemplated (Anon., 2004b:3).

A problem with especially diesel vehicles is the emission of particulate matter. To combat this problem filters are being designed to trap these particles in the exhaust system of a vehicle (Anon., 2004a:1). These systems are designed to regenerate automatically either in a passive manner through constant heating, or an active manner where electronic monitoring will trigger active regeneration.

Different technologies are available for the capturing of nitric oxides (NO_x). One of these is the selective catalytic reduction (SCR) system. The system uses urea which is added to the exhaust stream. It decomposes to form ammonia which is then used to reduce the NO_x. The drawback of this system is firstly that the amount of urea needs to be altered with the change of speed and load of the vehicle. Secondly the urea has to be transported in a separate tank that needs regular refilling. Despite these drawbacks it is used widely in Europe.

A second newer technology is the plasma fuel reformer. With this system hydrogen rich gas is generated on board using diesel. It is then used to effectively regenerate the NO_x trap (Anon., 2004a:2).

These technologies are not currently widely used locally and although they provide solutions for some of the problems, they may prove to be too expensive to implement on a larger scale.

An alternative solution is to improve the management of the vehicle fleet in urban areas. One of these is the implementation of public transport systems to reduce the number of vehicles in cities. This is a common measure implemented in the United Kingdom. Locally this will be a challenge since implementing transport networks in already developed urban areas is significantly more difficult than designing them during the development of a city or town. Another example is the city of Athens, where vehicles with odd and even numbered registration numbers are allowed in the city on different days when inclement weather conditions cause high levels of air pollution.

The bottom line is that something will have to be done locally to control urban vehicle emissions. Whether it will include some of the abovementioned technologies and solutions will have to be decided by the local government. According to Munn and Kornelius (2002:5) failure to address the vehicle emission problem can even put huge strain on the industrial sector. Houston was quoted as an example where traffic emissions had increased to such an extent that the allowable industrial emissions from the commercial sector had to be halved.

4.5 Health impact in South Africa

Blood lead levels are an indicator of the exposure of humans to lead. According to Diab (1999:117) blood lead levels around the world have decreased with the introduction of unleaded fuel.

Studies conducted in South Africa in the past few years clearly indicated that many children have unacceptably high blood lead levels. Studies done in the Cape Peninsula area has indicated the blood lead levels of children living in urban areas tend to be double that of children from suburban areas (Von Schirnding *et al*, 1991:454). Epidemiological studies undertaken in cities have shown that over 90% of children have elevated lead levels in their blood (Mathee *et al*, 2002:1). Especially children living near busy roads are at risk. A fact that is often overlooked is the time spent at day care centres. There a child may be exposed to factors very different from their home environments since many child care centres are located next to busy roads where the lead levels have been proved to be higher (John *et al*, 2004:135). It is suggested that the location of these centres be managed better. Busy roads, intersections and steep sloping roads enhance the emission of lead from vehicles. These areas have proved to have higher lead deposits. Cleaning practices at day care centres should also not involve appliances and methods that disperse dust.

Even children from rural populations seem to have elevated blood lead levels, which indicate that lead contamination is a huge problem in the country (Mathee & von Schirnding, 1999:15).

A study conducted by Diab in 1999 clearly indicates that the introduction of unleaded fuel, although not widely used, had a significant impact on the atmospheric lead levels in South Africa. Atmospheric lead levels in Durban were divided into three categories, the first being prior to any lead restrictions, the second for the period of January 1989 to January 1996 when lead was lowered to 0.4g/l and a third after the introduction of unleaded fuel. The results show an average reduction of 80% in atmospheric lead (Diab, 1999:119). The introduction of unleaded fuel has therefore had a significant positive effect on the atmospheric air quality.

According to Von Schirnding *et al* (2001:872) some studies have revealed that the decline in blood lead levels have not been as significant as expected since the introduction of unleaded fuel. Children from selected areas in the Cape Peninsula were tested for blood lead content. Samples were obtained from 510 children. The results were compared to samples taken in 1991. Although the blood lead levels varied from one school to another no significant drop in lead levels could be detected. This may be attributed to a variety of factors including the following:

1. Although lead levels in fuel have been reduced, environmental levels were still too high to make a significant impact on blood lead levels.
2. An increase in traffic could counter the effect of reduced lead levels.
3. Reduction in air lead concentrations may not necessarily be related to a reduction in dust lead levels.

(Von Schirnding *et al*, 2001:872).

It is therefore clear that the removal of lead from fuel is not enough to combat the health problem in South Africa.

Although the removal of lead from fuel has proven to have a positive effect on human health the introduction of new fuel seems to introduce a new health problem. According to Larbey (2004:15) the use of so-called cleaner fuels in vehicles not fitted with catalytic converters can cause the emission of even more harmful pollutants. This is a health hazard that can not be ignored and needs further investigation. To simply replace one hazardous substance with another is clearly not the desired option.

Fuel is however not the only culprit. Studies done in the Cape Peninsula area indicated that apart from environmental factors, social factors play a significant role in lead exposure. In areas of lower social-economic status, old homes in need of repair, overcrowding of homes, and less adult supervision tend to contribute to exposure to lead sources (Von Schirnding *et al*, 1991:546).

Children are more at risk to picking up lead poisoning because of their tendency to ingest soil and paint chips through the so-called pica phenomena (Mathee, 2003:1). According to the South African Medical Research Council (MRC) many children are exposed to lead risks in their own homes and schools due to the use of lead based paints. It is a particular problem in rural areas. It is estimated that up to 20% of schools and houses contain these paints (SABC News, 2004).

Despite the South African paint industry's voluntary agreement to limit the use of lead, it seems that leaded paint is still being used. Lead-based paints have been detected in recently developed suburbs, indicating that it is still readily available locally. The levels of lead in paint samples taken in some home environments were very high, measuring up to 46 000 µg/g. This is nine times higher than the USA standard (Medical Research Council, 2004b:1). According to Mathee lead is used widely in both well known and lesser known brands, particularly in orange, yellow and red enamel paints (Caelers, 2004).

Many paint manufacturers have committed to not using lead in their products such as *Plascon*, who state on their web site: "As a responsible paint manufacturer, *Barloworld Plascon* assures our customers and consumers that none of our decorative products contain any lead whatsoever" (Plascon, 2004).

Not all manufacturers are however committed to this cause, and stricter legislation is required.

There are currently no paint lead level standards in place in South Africa to protect the general public against this risk (Medical Research Council, 2004b:1). According to Angela Mathee "A nation-wide campaign to improve public awareness of the hazards of lead exposure is now long overdue, and needs to be implemented as a matter of urgency, together with the provision of blood lead testing facilities, especially in high risk areas".

In a case study conducted by the MRC, a 7-year-old girl was revealed to have a blood lead level of 51.5g/dl, which is five times higher than the internationally accepted action level of 10g/dl. Upon investigation of the subject's home and school environments it was found that paint in both these areas contained high levels of lead. Since the child was know to demonstrate the pica tendency it was concluded that the paint was the source of the elevated blood lead level (Mathee *et al*, 2002:1). The case study concluded that actions to prevent this kind of exposure should be implemented.

It is clear that exposure to lead through paint has to be addressed. Suggestions included the following (Mathee *et al*, 2002:1):

1. Research and surveillance programs should identify the high risk areas.
2. Improved access to information on lead exposure should be made generally available.
3. Standards for childhood blood levels need to be developed.
4. Implementation of the regulation of maximum lead levels in paints, children's toys, furniture etc must occur.

Of particular concern to the Council is the low level of awareness among the public regarding this health hazard. According to Mathee (2003:30) public awareness needs to be raised especially amongst parents, educators and health workers.

The informal sector further contributes to this problem. Many home based industry activities such as repairing of motor vehicles, work on lead batteries and repairs to appliances using lead solder can pose a risk to young children. Lead particles can also be transported from the workplace to the home by means of clothes, shoes and hair (Medical Research Council, 2004b:1). Probably the largest challenge facing the community is the safe removal of lead based paint from existing structures. Special precautions have to be followed to limit exposure to the lead containing dust.

A research program by the MRC is currently planned on behavioural intervention to reduce blood lead levels. It will focus on an awareness campaign, which will encourage regular hand washing and damp dusting and mopping. Blood levels will be monitored simultaneously (Mathee, 2003:30). Implementation will be crucial to combat the existing problem.

4.6 Alternative fuel additives

With alternative fuel additives such as MMT and MTBE still under scrutiny, the question remains what additive will be suitable in future.

MTBE which was one of the preferred new additives proved to have a detrimental effect on groundwater quality. Although it was only introduced in the 1970's, alarming levels of the chemical have been detected in aquifers were the fuel additive has been used (Geiselman, 2003). In the United States research work on remediation and treatment of these contaminated water holdings have received a lot of attention, all because sufficient research was not done prior to the introduction MTBE to fuel.

The use of MMT is continuing, but there are no conclusive results to indicate that it is safe. According to Solomon (1996) further research on the distribution, fate and ecosystem effects of manganese is required. In response to the potential effect of MMT on human health the Health and Development Research Group from the MRC undertook a baseline study of manganese blood levels of a group of grade one pupils from across the country in 2004. Preliminary results indicated higher levels of manganese in Johannesburg children than those of Cape Town. A portion of the children already had manganese blood levels that were higher than international accepted standards (Medical Research Council, 2004a:4).

Time is however quickly running out; worldwide the rapid phase out of leaded fuel is demanded, but it is apparent that an ideal alternative has not yet been identified. Even ethanol, identified as an option for many years, has drawbacks as discussed earlier.

In South Africa the added disadvantage is that a large portion of the vehicle fleet is not fitted with catalytic converters. Even if these vehicles are compatible with the new additives, it may cause additional emissions as result of the absence of these devices. With that large number of older vehicles in the local vehicle fleet, lead replacement fuel will be required for some time in the future. The identification of a suitable alternative which will not be environmentally hazardous is therefore crucial.

4.7 Future situation

As from 1996 the USA has been using exclusively unleaded fuel (Kitman, 2000). If the South African legislation comes into effect in 2006, as proposed, South Africa will be in a similar situation, only ten years later. Whether this will have the desirable effect on the quality of ambient air and therefore human health is yet to be proven.

Future developments are following the trend of producing so-called "greener" fuel. *Sasol* is currently involved in a gas to liquid (GTL) technology project in Qatar, planning to produce cleaner diesel. The produced fuel will contain less that 5 ppm of sulphur, which is much lower than the 500 ppm specification set by the VES for 2006. *Sasol* Spokesman, Pat Davies, remarked that he believes that the GTL industry will grow rapidly in the future (Botha, 2001:45).

A suitable alternative for lead is required. Alternatives have been introduced, but their potential adverse effect on human health is still being debated. The situation where one harmful substance is replaced with another should be avoided at all cost.

In the light of the government's vehicle emission strategy, the legislation on vehicle emissions will also affect the consumer. It is foreseen that vehicle owners will be obliged to ensure that their vehicles are maintained in such a manner that emission levels prevail with levels at the time of manufacture (SA, 2003:23).

There will also be extensive pressure on traffic departments to enforce the new vehicle emission standards. Vehicle testing stations will have to be built and trained operating personnel have to be appointed. In Illinois, USA the testing consists of the following (Illinois Environmental Protection Agency, 2004):

1. A certified officer has to enter the vehicle data into a computer system
2. The vehicle is placed in position and emissions are gathered from the tailpipe of the vehicle and analyzed.
3. The results are compared to standards and a report is printed.
4. If the vehicle passes the test a compliance certificate is issued.
5. If the vehicle fails the test, the report and a repair diagnostic report is issued.

Testing is therefore quite complicated and the implementation of such a system in South Africa will be costly.

According to Paxton (2000:1) the problems relating the pollution caused by vehicles can not simply be solved by changing fuel and fitting catalytic converters to motor vehicles. The growing number of vehicles on the South African roads calls for a serious look at the development of an efficient public transport system.

The Gautrain Rapid Rail Link is one such a project aiming to ease the burden on the highways in the Gauteng area. The proposed rapid rail network will consist of two links, one between Pretoria and Johannesburg and one between the Johannesburg International Airport and Sandton. This modern train will be the first of its kind in South Africa and will offer a public transportation system of international standard. It will travel at a maximum speed of 180 kilometres per hour and passengers will be able to travel between Johannesburg and Pretoria in approximately 40 minutes (Gauteng Corporate, 2004). The original date set for commencement of construction was middle of 2004, but due to delays surrounding the EIA for the project, construction will now only commence somewhere in 2005/6. Completion for the first phase is proposed for 2008 and completion of phase two of the project is estimated towards the middle of 2010. This project is said to be the first of more projects planned towards creating a new culture of public transport in South Africa.

If successful this project can contribute significantly to the decrease of vehicles on roads in Gauteng. This will hopefully contribute to a reduction in exhaust emissions and subsequent improvement of air quality in future.

5. Findings

The phase out of leaded fuel in South Africa will most definitely have a positive effect on the reduction of lead-related health impacts. Leaded fuel has internationally been identified as one of the main contributors to the high levels of lead found in the natural environment. Sulphur reduction will lower the levels of particulate emissions resulting in an improvement of ambient air quality.

A secondary effect of the change in fuel legislation is the implementation of catalytic converters. The increase in use of motor vehicles fitted with emission control systems will have a further positive effect on air quality, especially in urban areas.

A very small percentage of South African vehicles are however currently fitted with catalytic converters, and it is anticipated that the introduction of new fuels will not have a significant effect immediately. According to the Automobile Association (2005:1) older cars not fitted with catalytic converters produce up to twenty times the emissions of a car manufactured today. Although more newly manufactured vehicles will have these devices the majority of the existing South African vehicle fleet will not. This poses a huge problem since the new fuels generally tend to have a higher aromatic and oxygenate content. These additives cause excessive emissions if used without a catalytic converter and therefore the introduction of new fuels locally can potentially have an even worse effect on ambient air quality in the interim period.

Leaded fuel is not the only source of lead that affects human health in South Africa. Other sources of lead as discussed include use of leaded paint, renovation of houses with chipping and peeling paint, and lead related industries such as pottery and ceramic factories, radiator repair and battery recycling plants (Tran, 2001).

Specific measures must also be implemented to prevent further exposure, as suggested by Tong *et al* (2000:1073):

1. Total phase out the use of lead in paint.
2. Eliminating the use of lead in food containers.
3. Improving control over lead exposure in work places.
4. Increased control overt the use of lead in water treatment.

The main problem with lead poisoning locally, is the ignorance of local South Africans. The community is not aware of the risks associated with exposure to lead sources. As mentioned by the MRC, education regarding exposure to existing lead hazards needs particular attention.

The phase out of leaded fuel will have a significant financial impact on the fuel producing industry. Huge financial input has been required to convert the existing facilities to meet the new fuel specifications. To date there has been no indication that this process will be subsidised by the government.

An ideal replacement for tetraethyl lead has not yet been identified. Although suitable alternatives have been recognised, mayor controversy surrounds the potential effect that these alternatives may have on human health and the environment. South Africa has a large number of older vehicles which will require LRF with a suitable alternative additive.

Apart from the Vehicle Emission Strategy issued in 2003 no practical plans have been derived for vehicle emission control. Many vehicles will not comply with the proposed emission standards. The impact of the introduction of cleaner fuel will have to be accompanied by a national effort to reduce vehicle emissions in general. There are significant challenges for the practical implementation of the required management of vehicle emission standards.

The average emission levels for vehicles vary according to the distribution of a country's vehicle fleet. The UK is currently struggling to meet the Euro emission standards. This can be mainly attributed to the fact that their vehicle fleet differs from that of typical European countries such as Spain and France. The fact that these countries have a large sector of small cars which generally have lower fuel consumption and CO_2 emissions contribute to their ability to reach the set targets (Fowler, 2004:9). In the light of this South Africa, with is large section of old vehicles, will have even more difficulty to achieve these new emission targets.

6. Conclusions and recommendations

The three research questions that needed to be answered were firstly: Will the new legislation will have a significant positive effect on the current air quality and therefore on the health of the general public?

The answer to this first question is yes and no. That the phase out is going to have a positive effect on the ambient air quality of South Africa is true when one purely evaluates lead levels. The elimination of lead from fuels will discontinue the growing deposit of lead particles in the environment. As indicated by several studies this will contribute to the reduction of blood lead levels in humans, and hopefully particularly in that of children. This should therefore have a significant positive effect on human health.

It will also aid the use of catalytic converters that will result in lower exhaust emission levels. Photochemical smog is a significant environmental problem in urban areas and the increased number of catalytic converters should have a positive effect on the ambient air quality. This will however only reach its full potential when a significant percentage of the local vehicle fleet is fitted with emission control systems.

In the interim period the introduction of unleaded fuel may have a negative impact on the ambient air quality. Although lead is eliminated the unleaded fuel may cause even more emissions since the majority of South African vehicles are not fitted with catalytic converters.

In the long run the effect on air quality will therefore be positive but until a larger percentage of vehicles are fitted with catalytic converters one pollutant may sadly simply be replaced by another. As suggested by Larbey (2004:15), South Africa's unique vehicle fleet dynamics should have been taken into account when developing the phase out program. Since this was not done the local government with have to seriously consider programs to speed up the introduction of catalytic converters to all vehicles.

It should also be considered that leaded fuel be available on a limited scale for a longer period to accommodate older vehicles. The additives can also be sold separately for a longer period to accommodate this problem.

The second research question asked for the investigation of the secondary effects that the new legislation may bring about. As mentioned the introduction of new fuel legislation will have a significant financial impact on the fuel manufacturing industry. This has been determined and probably this is a burden that the industry will have to carry without any compensation from government.

The economic implications to both the commercial and private sectors are difficult to determine and may require more in-depth research that is beyond the scope of this dissertation.

The search for a suitable lead alternative is still ongoing. Alternatives such as MTBE have proven to have environmental impacts that were only realised some years after its implementation. The full impact of the current identified alternatives is not yet known and therefore the health impact can not be determined for certain. The thorough testing of new additives is therefore crucial. In the light of sustainable development it is vital that the mistakes of the past are not repeated.

Lastly the aim of this dissertation was to suggest additional mitigation measures that have to be implemented to ensure an overall positive effect on ambient air quality.

Whether South Africa is capable of managing the challenges with the proposed introduction of emission standards is still to be proven. It has to be kept in mind that South Africa is a developing country in comparison with European standards.

Even though there is a fairly large sector of the community with new vehicles which will meet the new emission standards, a significant number of vehicles on South African roads will not meet these specifications. Currently the average motor vehicle on the local roads is estimated to be ten years old. These vehicles do not meet the stricter emission control standards and getting them up to standard will be a costly exercise. This is a cost that the average South African motor vehicle owner will most probably not be able to meet.

To simply change the fuel will not solve the problem of air pollution. Stricter governance in emission control is required. Apart from the cost to the individual the South African government will have to provide funds for the establishment of a body to govern the emission standards. This body will have to monitor vehicles on a regular basis similar to the management of the current drivers licence system. Vehicle testing stations will also have to be established on a national level, incurring even more costs. In order to cover these costs the regular testing will most probably also have to be subject to a fee to be paid by the motor vehicle owner.

It is therefore recommended to introduce this system in a phased program. This will allow sufficient time for the introduction of new and stricter standards over a period of time to suit government and vehicle owners alike. With a more lenient schedule implementation will probably be more efficient.

The introduction of vehicle emission monitoring will be crucial to ensure better air quality. The Cape Metropolitan Administration has initiated a control programme as early as 1999 (City of Cape Town, 2004:1). They identified diesel vehicle emissions as one of the major contributors to smog and despite the outdated air quality legislation decided to put mitigation measures in action. In December 1999 they appointed three diesel vehicle-testing teams. Diesel vehicles are submitted to an emission test and owners of vehicles that fail need to repair these vehicles, face prosecution. The introduction of a similar program on a national level is highly recommended.

For South Africa, a developing country, this will however be very costly. The testing of vehicles will have to be co-ordinated by the government. In the USA the EPA started by co-coordinating the testing of new vehicles. As time went by, this testing was transferred to the vehicle manufacturers. The problem was however that these tests were than rendered confidential. The Ethyl Corporation took the EPA to court, claming that this practice violated the US Clean Air Act that specifies that the EPA must "by regulation establish methods and procedures for making tests" (Dennis-Parker, 2003:799). The court ruled in favour of the Ethyl Corporation and the EPA had to develop a new testing program. The court stated that the long term benefit of improving air quality could not be accomplished by private business. Testing can therefore not be left in the hands of motor vehicle manufacturers.

The existing problems have to be addressed as well. There are already huge deposits of lead in the South African environment. Because of increased industrialisation and the associated persistence of lead in the environment, exposure of humans to this hazard is likely to remain a significant public health problem in the future (Tong *et al*, 2000:1073). Although the measures listed above can prevent additional lead depositing, the existing lead will not disappear.

As the Medical Research Council (MRC) found there are many sources of lead that need to be identified. The community must be educated regarding the prevention of lead poisoning. The MRC is actively involved in this process, and support for their efforts is crucial. High risk populations need to be identified and action plans put in place there to prevent unnecessary exposure. The location of especially day care centres and pre-schools, also have to be managed more strictly.

The South African Transport system can also be altered to decrease the number of vehicles on the local roads. Alternatives to consider in future include the establishment of efficient public transportation systems. This would not only contribute to less vehicle emissions, but also ease the load on urban roads. It can also be considered to invest in the improvement of the existing rail transport system. If this service could be more reliable and dynamic more commercial goods can be transported by rail. This could significantly decrease the number of heavy vehicles on national roads.

Finally a national awareness campaign to educate motorists on the proposed octane levels of the new fuels would probably be advisable. Motor vehicle owners must be informed of the changes that may be expected (Mawson, 2004:2). This could also include information regarding the proposed vehicle emission strategy.

As mentioned before the introduction of new legislation of this magnitude is not a task to be taken lightly. As discussed above, there are many challenges that await the government organisations tasked to implement the new legislation and the associated control measures. All sectors of the South African society will be affected to some extent and as with any change it is destined to generate some resistance.

It can be concluded that the intention of the new fuel legislation is justified. It must however be kept in mind that change is never uncomplicated and that the secondary effects associated with change cannot be ignored. With sound planning and careful execution the South African government will hopefully be able to meet these challenges. If implemented successfully it would be a noble example of sustainable development in a developing country.

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