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.