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The Impact of Fuel Parameters on Vehicle Emissions

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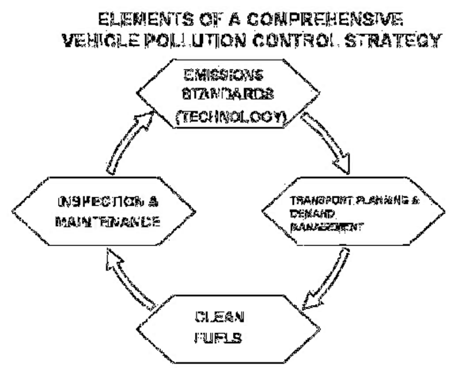
1. Background and Introduction

Motor vehicles emit large quantities of carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and such toxic substances as benzene, formaldehyde, acetylaldehyde, 1,3,butadiene, fine particles (PM), and lead (Pb). Each of these, along with secondary by-products such as ozone, can cause serious adverse effects on health and the environment. Because of the growing vehicle population in most Asian countries especially China and the high emission rates from many of these vehicles, as well as emissions from other sources, serious air pollution and associated adverse health problems have been increasingly common phenomena in modern life.[1]

Reducing the pollution that comes from vehicles will usually require a comprehensive strategy that includes four key components: emissions standards for new vehicles, specifications for clean fuels, programs to assure proper maintenance of in-use vehicles, and transportation planning and demand management. One important lesson that has been learned is that vehicles and fuels should be treated as a system. These emission reduction goals should be achieved in the most cost effective manner available.



Over the last fifteen years, extensive studies have been carried out to better establish the linkages between fuels and vehicles and vehicle emissions. One major study, the Auto/Oil Air Quality Improvement Research Program (AQIRP) was established in 1989 in the US and involved 14 oil companies, three domestic automakers and four associate members[2]. In 1992, the European Commission also initiated a vehicle emissions and air quality program. The motor industry (represented by ACEA) and the oil industry (EUROPIA) were invited to cooperate within a framework program, later known as "the tripartite activity" or European Auto/Oil Program. In June 1993, a contract was signed by the two industries to undertake a common test program, called the European Program on Emissions, Fuels and Engine Technologies (EPEFE).

Relying heavily on these studies, the purpose of this paper is to summarize what is known about the impact of fuel quality on emissions. It will conclude by highlighting the critical fuels challenges for China.

2. Diesel Fuel

[1] **Review of Studies of Health Effects of Outdoor Air Pollution in the Developing Countries of Asia,** Health Effects Institute, 2004

[2] "Auto/Oil Air Quality Improvement Research Program, Final Report", January 1997.

Diesel fuel is a complex mixture of hydrocarbons with the main groups being paraffins, napthenes and aromatics. Organic sulfur is also naturally present. Additives are generally used to influence properties such as the flow, storage and combustion characteristics of diesel fuel. The actual properties of commercial automotive diesel depend on the refining practices employed and the nature of the crude oils from which the fuel is produced. The quality and composition of diesel fuel can significantly influence emissions from diesel engines.

Diesel vehicles emit significant quantities of both NOx and particulate. Reducing PM emissions from diesel vehicles tends to be the highest priority because PM emissions in general are very hazardous and diesel PM, especially, is likely to cause cancer. To reduce PM and NOx emissions from a diesel engine, the most important fuel characteristic is sulfur because sulfur in fuel contributes directly to PM emissions and because high sulfur levels preclude the use of the most effective PM and NOx control technologies.

A. Impact of Diesel Fuel Composition on Asian Vehicle Emissions[3]

The following tables summarize the impacts of various diesel fuel qualities on emissions from light and heavy duty diesel vehicles, respectively.

Impact of Fuels on Light Duty Diesel Vehicles

Diesel Fuel Characteristic	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5[4]	Comments
Sulfur↑	SO_2, PM↑		If ox cat, SO_3, SO_2, PM↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NOx adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane↑	Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density↓	PM, HC, CO, formaldehyde, acetaldehyde & benzene↓, NOx↑						
Volatility (T95 from 370 to 325	NOx, HC increase, PM, CO decrease						

[3] Most Asian countries including China have linked their vehicle emissions control programs to the EU or ECE requirements so much of the discussion that follows will relate fuels parameters to different technologies meeting EU standards.

[4] Euro 5 emissions standards for light duty diesel vehicles have not yet been adopted by the EU. However, the EU Commission has indicated that it will propose these standards during 2005 and they will likely become mandatory during the period from 2008-2010. It seems likely that these standards will mandate the use of PM filters on all light duty diesel vehicles.

C)		
Polyaromatics↓	NOx, PM, formaldehyde & acetaldehyde↓ but HC, benzene & CO ↑	some studies show that total aromatics are important

Impact of Fuels on Heavy Duty Diesel Vehicles

Diesel	Pre-Euro	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5[5]	Comments
Sulfur↑	SO_2, PM↑		If ox cat, SO_3, SO_2, PM↑		If Filter, 50 ppm maximum, 10-15 ppm better		If NOx adsorber used requires near zero sulfur (<10 ppm) With low S, use lubricity additives
Cetane↑	Lower CO, HC, benzene, 1,3 butadiene, formaldehyde & acetaldehyde						Higher white smoke with low cetane fuels
Density↓	HC, CO ↑, NOx↓						
Volatility (T95 from 370 to 325 C)	Slightly lower NOx but increased HC						Too much heavy ends increases smoke and PM
Polyaromatics↓	NOx, PM, HC ↓						Some studies show that total aromatics are important

B. Impact of Specific Diesel Fuel Parameters

Higher **sulfur** content will tend to increase sulfur dioxide (SO_2) and PM emissions from all vehicle categories, from the least controlled to the most controlled. Sulfur dioxide is an acidic irritant that also leads to acid rain and the formation of sulfate particulate matter. As vehicle emissions standards are tightened to Euro 2 and Euro 3 levels, oxidation catalysts will tend to be introduced to reduce PM emissions but these systems will also tend to convert some of the SO_2 into more hazardous SO_3 emissions which when combined with water vapor leads to sulfuric acid mist (H_2SO_4). Further tightening of vehicle emissions standards will tend to require the introduction of PM filters on many vehicles and while these systems can largely eliminate PM emissions they tend to be very sensitive to sulfur levels in fuel. It is generally recommended that maximum sulfur levels with these systems be reduced to 50 ppm or less; many of these systems give

[5] The EU Commission has also indicated that it will propose Euro 6 emissions standards for heavy duty engines during 2005, likely mandating the use of PM filters on all heavy duty diesel vehicles from 2010 or 2012.

optimum performance with fuels having sulfur levels in the range of 10 to 15 ppm or less. NOx control systems for diesel vehicles are still evolving with the two major candidates for Euro 4 and Euro 5 vehicles being Selective Catalytic Reduction (SCR) Systems which are not especially sensitive to sulfur levels in fuel[6] and NOx adsorber systems which are extremely sensitive to sulfur and require levels in the range of 10 to 15 ppm or less.

Cetane number is a measure of auto-ignition quality. High cetane number fuels enable an engine to be started more easily at lower air temperatures, reduce white smoke exhaust, and reduce diesel knock. An increase in cetane number generally results in a decrease in carbon monoxide, hydrocarbons and nitrogen oxides emissions (most notably in heavy duty engines), as well as in benzene, 1,3 butadiene, formaldehyde and acetaldehyde emissions from light duty engines. For diesel vehicles equipped with oxidation catalysts or catalyzed PM filters, emissions of CO, HC and the toxics, benzene, 1,3 butadiene, formaldehyde and acetaldehyde, will tend to be less sensitive to cetane number. While one major study (the EU EPEFE study) found that particle emissions increased from light duty vehicles as the cetane number increased (no significant effect was seen in heavy duty engines) other research has suggested that an increase in cetane number can lead to lowered particle emissions.

Density relates to the energy content of fuel; the higher the density of the fuel the higher its energy content per unit volume. Too high a fuel density for the engine calibration has the effect of over-fuelling, increasing black smoke and other gaseous emissions. The European EPEFE study found that:

- For light duty vehicles, reducing fuel density decreased emissions of particles, hydrocarbons, carbon monoxide, formaldehyde, acetaldehyde and benzene; increased emissions of NOx; but had no impact on the composition of the particle load.

- For heavy duty vehicles, reducing fuel density decreased emissions of NOx; increased emissions of hydrocarbons and carbon monoxide; but had no impact on particle emissions or the composition of the particle load.

CONCAWE investigations have shown that changes to engine calibration can considerably reduce the impact of changes in density (and viscosity) on emissions. Density effects could therefore be compensated for by changes in engine calibration.

The **distillation** curve of diesel fuel indicates the amount of fuel that will boil off at a given temperature. The curve can be divided into three parts: the light end, which affects startability; the region around the 50% evaporated point, which is linked to other fuel parameters such as viscosity and density; and the heavy end, characterized by the T90,[7]

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[6] While SCR systems themselves are not particularly sensitive to sulfur levels, they tend to be combined with an oxidation catalyst to reduce ammonia slip and these oxidation catalysts are sensitive to sulfur levels. Sulfate emissions levels will also tend to increase with oxidation catalysts and higher sulfur fuels.

[7] The temperature at which 90% of the fuel will evaporate.

T95 and final boiling points. Investigations have shown that too much ‘heavy ends’ in the fuel’s distillation curve can result in heavier combustion chamber deposits and increased tailpipe emissions of soot, smoke and particulate matter. The effect of T95 on vehicle emissions was examined in the EPEFE study which indicated that exhaust gas emissions from heavy duty diesel engines were not significantly influenced by T95-variations between 375°C and 320°C. However, a tendency for lower NOx and higher hydrocarbon emissions with lower T95 was observed.

Polyaromatic hydrocarbons (PAHs) are increasingly attracting special attention because many are known human carcinogens. Testing for the EU EPEFE study showed that:

- For light duty vehicles reducing polyaromatics decreased NOx, particles, formaldehyde and acetaldehyde emissions, but increased hydrocarbon, benzene and carbon monoxide emissions.
- for heavy duty vehicles, reducing polyaromatics decreased NOx, particles and hydrocarbon emissions

3. Gasoline

Gasoline is a complex mixture of volatile hydrocarbons used as a fuel in internal combustion engines. The pollutants of greatest concern from gasoline-fuelled vehicles are CO, HC, NOx, lead and certain toxic hydrocarbons such as benzene. Each of these can be influenced by the composition of the gasoline used by the vehicle. The most important characteristics of gasoline with regard to its impact on emissions are – lead content, sulfur concentration, volatility, aromatics, olefins, oxygenates, and benzene level.

A. Impact of Gasoline Composition on Asian Vehicle Emissions.

The following tables summarize the impacts of various diesel fuel qualities on emissions from light duty gasoline vehicles.

Impact of Gasoline Composition on Emissions from Light Duty Vehicles

Gasoline	No Catalyst	Euro 1	Euro 2	Euro 3	Euro 4	Euro 5	Comments
Lead ↑	Pb, HC↑	CO, HC, NOx all increase dramatically as catalyst destroyed					
Sulfur ↑ (50 to 450 ppm)	SO_2 ↑	CO, HC, NOx all increase ~15-20% SO_2 and SO_3 increase					MIL light may come on incorrectly
Olefins ↑	Increased 1,3 butadiene, increased HC reactivity, NOx, small increases in HC for Euro 3 and cleaner						Potential deposit buildup

Aromatics ↑	Increased benzene in exhaust					Deposits on intake valves and combustion chamber tend to increase
	potential increases in HC, NOx	HC↑, NOx↓, CO↑		HC, NOx, CO ↑		
Benzene ↑	Increased benzene exhaust and evaporative emissions					
Ethanol ↑ up to 3.5% O_2	Lower CO, HC, slight NOx increase(when above 2% oxygen content), Higher aldehydes	Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems				Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty
MTBE ↑ up to 2.7% O_2	Lower CO, HC, higher aldehydes	Minimal effect with new vehicles equipped with oxygen sensors, adaptive learning systems				Concerns over Water Contamination
Distillation Characteristics T50, T90↑	Probably HC↑	HC↑				
MMT ↑	Increased Manganese Emissions			Possible Catalyst Plugging	Likely Catalyst Plugging	O_2 sensor and OBD may be damaged, MIL light may come on incorrectly
RVP ↑	Increased evaporative HC Emissions					Most critical parameter for Asian countries because of high ambient Temperatures
Deposit control additives ↑		Potential HC, NOx emissions benefits				Help to reduce deposits on fuel injectors, carburetors, intake valves, combustion chamber

B. Impact of Specific Gasoline Parameters

Lead additives have been blended with gasoline, primarily to boost octane levels, since the 1920s but there is now a clear worldwide trend to eliminate their use and most Asian countries have done so. Lead emissions from all vehicles using leaded gasoline increase in direct proportion to the amount of lead consumed. This lead is toxic and has long been recognized as posing a serious health risk especially for children. In addition, vehicles using leaded gasoline cannot use a catalytic converter (required to comply with Euro 1 emissions standards or tighter) and therefore have much higher levels of CO, HC and NOx emissions. Fortunately, lead has been banned from all gasoline sold in China for several years.

Sulfur dioxide emissions increase from all categories of gasoline fueled vehicles in direct proportion to the amount of **sulfur** in fuel. Sulfur dioxide is an acidic irritant that also leads to acid rain and the formation of sulfate particulate matter. Its greatest impact, however, is in vehicles equipped with catalytic converter technology, required for compliance with Euro 1 or tighter vehicle emissions standards. Testing of catalysts has demonstrated reductions in efficiency resulting from higher sulfur levels across a full range of air/fuel ratios. The effect is greater in percentage for lower emission vehicles (Euro 3, 4 and 5) than for less controlled vehicles (Euro 1 or 2). The durability of catalysts is also impacted by sulfur levels in fuels as active catalyst sites tend to get coated with sulfur compounds. Studies have also shown that sulfur adversely affects heated exhaust gas oxygen sensors; slows the lean-to-rich transition, thereby introducing an unintended rich bias into the emission calibration; and may affect the durability of advanced on-board diagnostic (OBD) systems.

The lean-burn gasoline engine with direct fuel injection which is emerging makes possible a 15% decrease in fuel consumption compared with conventional gasoline engines thereby reducing greenhouse emissions. In Europe, there is a clear recognition that to be able to comply with future ‘severe emissions limit values’, the use of NOx accumulator DeNOx catalytic converters will be necessary. Even low levels of sulfur in fuel lead to deterioration in the accumulation capacity of this catalytic converter and make more frequent regeneration intervals necessary, which causes an increase in fuel consumption. A reduction of the fuel sulfur content from 50 to 10 ppm lowers the frequency of the regeneration intervals, and decreases fuel consumption; with sulfur levels above 50 ppm, DeNOx catalysts are not feasible.

The EU EPEFE study found that reducing sulfur from 382 to 18 ppm reduced exhaust emissions of HC, CO and NOx (the effects were generally linear at around 8-10% in urban driving and 20 to 50% in high speed driving). In the case of air toxins, benzene and C3-12 alkanes were in line with overall hydrocarbon reductions, with larger reductions (around 18%) for methane and ethane.

Gasoline **volatility** is an indication of how readily a fuel evaporates and is characterized by two measurements – vapor pressure and distillation. High gasoline **vapor pressure** causes high evaporative hydrocarbon emissions which can comprise a large part of total hydrocarbon emissions. Their release may occur during the delivery and transfer of gasoline to storage, vehicle refueling, the diurnal breathing of vehicle fuel tanks (as they heat up and cool down with normal daily temperature variations), and the fugitive losses that occur from carburetors and other equipment during normal vehicle operation. Reductions in fuel volatility will significantly reduce evaporative emissions from vehicles. A reduction in vapor pressure is one of the more cost effective of the fuel-related approaches available to reduce hydrocarbon emissions.

Vapor pressure is most effectively managed on a regional and seasonal basis to allow for the different volatility needs of gasoline at different temperatures. The reduction of evaporative emissions is most effectively achieved when RVP is controlled when ambient temperatures are high – i.e. the summer period. Any associated cold weather driveability-related problems can be addressed by either restricting limits to the summer period, or by shortening the summer period and/or setting regional volatility limits to take into account both climatic and seasonal temperature profiles.

Distillation is a second method for measuring the volatility of gasoline. The EPEFE study found that increasing E100 in gasoline (the percentage of gasoline evaporated at 100°C) reduces emissions of hydrocarbons but increases NOx emissions. Increasing E100 from 35% to 50% by volume showed a decrease in mass emissions of both formaldehyde and acetaldehyde but increasing E100 from 50 % to 65 % by volume showed no clear effect.

Olefins are good high octane components of gasoline but they can lead to the build up of engine deposits and increased emissions of highly reactive ozone-forming hydrocarbons and toxic compounds. They tend to be chemically more reactive than other hydrocarbon types. A study by the US Auto/Oil program concluded that reducing total olefins from 20% to 5% would significantly decrease ozone-forming potential. Reduction of low molecular weight olefins accounts for about 70% of the ozone reduction effect. In addition, 1,3-butadiene, a known carcinogen, is formed during the combustion of olefin compounds in gasoline and is therefore reduced by lowering the olefin fraction in gasoline.

Aromatics are hydrocarbon fuel molecules based on the ringed six-carbon benzene series or related organic groups. Combustion of aromatics can lead to the formation of benzene in exhaust gas, a human carcinogen that can cause leukemia in exposed persons. Lowering aromatic levels in gasoline significantly reduces toxic benzene emissions from vehicle exhausts. In the EU EPEFE study, benzene emissions were found to vary between 3.6% and 7.65 % of total volatile organic compounds for fuel aromatic contents ranging from 19.5% to 51.1% by volume.

Benzene is a six-carbon, colorless aromatic that occurs naturally in gasoline and is also a product of catalytic reforming used to boost octane levels. Benzene in gasoline leads to both evaporative and exhaust emissions of benzene.

Oxygen is added to gasoline to improve combustion, to limit emissions of ozone precursors and carbon monoxide, and/or to raise octane levels. The principal oxygenates which are used today are ethanol and MTBE. Where ethanol is used, evaporative HC emissions can increase significantly if the RVP of the fuel is allowed to increase. Increases in NOx exhaust emissions can occur with either oxygenate when the oxygen content is higher than 2 weight %. (There is some debate regarding the NOx effect for newer technology vehicles.) The magnitude of the reductions in HC exhaust emissions depends upon the vehicle technology; while older (pre Euro 1) vehicles would experience some reductions in exhaust emissions, newer vehicles (Euro 1 and newer) with oxygen sensors and adaptive learning systems will experience little or no effects. HC emissions during storage and transportation depend upon the presence or absence of Stage I and Stage II vapor recovery systems. Carbon monoxide emissions can decrease by around 10% following an increase in gasoline oxygen content from 0 to 2% (by weight).

Certain other **additives** which are put into gasoline can also affect vehicle emissions. Methylcyclopentadienyl manganese tricarbonyl (**MMT**) when added to gasoline will increase manganese emissions from all categories of vehicles. Recent studies have increased concerns regarding these emissions[8]. For example, a study published by the Health Effects Institute (HEI) earlier this year explored the mechanisms for transporting manganese into and out of the brain. The authors report that the transport rate of manganese out of the brain is slower than the transport rate for manganese entering the brain, indicating that a mechanism exists by which manganese may accumulate in the brain with chronic exposure.[9] Other studies have shown that fine particles containing manganese can be absorbed into the blood through the lungs and ferried directly into the central nervous system and brain[10]. Manganese associated with fine particles also enters the brain directly via the nasal passages, which contain nerves that have been shown to transport manganese into the brain[11]. The impact of low-level, chronic exposures is unclear, especially for sensitive populations such as infants, pregnant women, the elderly, and people with liver disease or iron deficiencies[12]. Potential adverse

[8] International Council on Clean Transportation, Status Report Concerning the Use of MMT in Gasoline, September 2004, Katherine Blumberg and Michael P. Walsh.

[9] Yokel, R. A., and J. S. Crossgrove. 2004. Manganese toxicokinetics at the blood-brain barrier. Health Effects Institute Research Report Number 119.

[10] Dobson, A. W., K. M. Erikson, and M. Aschner. 2004. Manganese neurotoxicity. Annals of the New York Academy of Sciences 1012: 115–128. Zayed, J., B. Hong, and G. L'Esperance. 1999a. Characterization of manganese containing particles collected from the exhaust emissions of automobiles running with MMT additive. Environmental Science & Technology 33:3341-3346., Zayed, J., A. Vyskocil, and G. Kennedy. 1999b. Environmental contamination and human exposure to manganese – contribution of methylcyclopentadienyl manganese tricarbonyl in unleaded gasoline. Int Arch Occup Environ Health 72:7-13., Zayed, J., C. Thibault, L. Gareau, and G. Kennedy. 1999c. Airborne manganese particulates and methylcyclopentadienyl manganese tricarbonyl (MMT) at selected outdoor sites in Montreal. Neurotoxicology 21:151-157.

[11] Tjälve H., Henriksson J., Tallkvist J., Larsson B. S., and Lindquist N. G. 1996. Uptake of manganese and cadmium from the nasal mucosa into the central nervous system via the olfactory pathways in rats. Pharmacology & Toxicology 79:347-356.

[12] Zayed, J. 2001. Use of MMT in Canadian gasoline: Health and environmental issues. American Journal of Industrial Medicine 39:425–433., Mena I, Horiuchi K, Burke K, and Cotzias GC. 1969. Chronic manganese poisoning. Individual susceptibility and absorption of iron. Neurology. 19(10):1000-1006.

effects are expected to be subtle and difficult to detect, which could result in widespread damage before use is stopped.

Vehicle manufacturers have expressed concerns regarding catalyst plugging and oxygen sensor damage with MMT use which could lead to higher in use vehicle emissions especially at higher mileage. The impact seems greatest with vehicles meeting tight emissions standards and using high cell density catalyst substrates.

Deposit control additives can reduce the build up of deposits on various engine components including fuel injectors and carburetors thereby maintaining low emissions from vehicles.

C. Two and Three Wheeled Vehicles

Many countries and cities throughout Asia have much higher proportions of two and three wheeled vehicles than anywhere else in the world. China is the largest producer of these vehicles and has the largest population in the world. While emissions from these vehicles are expected to be influenced by fuel characteristics, there has been very little study focused on the impacts of specific fuel parameters on these vehicles. However, based on the limited available data and the combustion similarities between these and other internal combustion engines, these impacts are estimated to be as shown in the table below.

Impact of Gasoline Composition on Emissions from Motorcycles

Gasoline	No Catalyst	India 2005	Euro 3	India 2008	Taiwan Stage 4	Comments
Lead ↑	Pb, HC↑	CO, HC, NOx all increase dramatically as catalyst destroyed				
Sulfur ↑ (50 to 450 ppm)	SO_2 ↑	CO, HC, NOx all increase SO_2 and SO_3 increase				
Olefins ↑	Increased 1,3 butadiene, HC reactivity and NOx					Potential deposit buildup
Aromatics ↑	Increased benzene exhaust					
Benzene ↑	Increased benzene exhaust and evaporative emissions					
Ethanol ↑ up to 3.5% O_2	Lower CO, HC, slight NOx increase	Minimal effect with oxygen sensor equipped vehicles				Increased evaporative emissions unless RVP adjusted, potential effects on fuel system components, potential deposit issues, small fuel economy penalty

MTBE ↑ up to 2.7% O_2	Lower CO, HC	Minimal effect with ox. sensor equipped vehicles	Concerns over Water Contamination small fuel economy penalty
Distillation characteristics T50, T90 ↑	Probably HC↑	HC↑	Not as quantifiable as in passenger cars
MMT ↑	Increased Manganese Emissions	Possible Catalyst Plugging	With low cell density, catalyst plugging risk seems small but there are concerns regarding deposits on spark plugs and in the combustion chamber
RVP ↑	Increased evaporative HC Emissions		
Deposit control additives ↑		potential emissions benefits	Help to reduce deposits on fuel injectors, carburetors

Most two and three wheeled vehicles currently used throughout the region are not equipped with catalytic converters to control emissions. Therefore it would seem that the impact of the various fuels parameters will be similar to those from pre Euro 1 cars. Some catalysts are starting to enter the fleet as emissions standards are being tightened, especially in India, Taiwan and Europe. These vehicles are anticipated to be impacted by sulfur and lead in a manner similar to Euro 1 and 2 gasoline fueled cars. For two and three wheeled vehicles equipped with 2-stroke engines, the amount and quality of the lubricating oil is probably more important than fuel quality.

4. Challenges Ahead For China

China is making great progress in addressing its motor vehicle pollution control problems as evidenced by its recent move to adopt Euro 2 standards for new vehicles across the entire country. In addition, in anticipation of a further tightening of new vehicle emissions standards, the Beijing EPB recently adopted tighter standards for fuels, reducing sulfur levels for diesel and gasoline to 350 ppm and 150 ppm, respectively, by July 2005. In addition, while MMT is not explicitly banned, the new specification notes that “metal additives cannot be added which have adverse effects on exhaust treatment systems and human health.”

While this is a major step forward, it is critically important for the entire country to rapidly move in the same direction. The emissions performance of vehicles sold in Beijing will deteriorate if and when they are driven outside the city and exposed to higher levels of sulfur. Further, until and unless new information provides greater assurance that the use of MMT will not result in serious adverse health effects after prolonged use or cause damage to advanced vehicle pollution control systems, its use should be banned not only in Beijing but nationally.