Fuel quality standards

In setting fuel quality standards, policymakers should be guided by the following general principles:

- Implementing a successful systems approach to setting fuel standards requires institutional mechanisms that include a variety of stakeholders from government, private sector and civil society, and allows for extensive consultation. In countries where such an institutional mechanism is not yet in place, it should be created.
- Environmental and public health concerns are the driving force behind improvements in fuel quality, thus the Environment Department should have a major role in setting fuel standards.
- All countries should develop a short- and medium-term strategy that identifies standards to be adopted over the next several years, so as to allow fuel providers and the vehicle industry sufficient time to adapt.
- The main impediment to adopting state-of-the-art new vehicle emissions technology (equivalent to Euro 3 and 4) in Asia is fuel quality, especially lead and sulfur levels in gasoline and sulfur levels in diesel. These parameters should receive the highest priority in the development of medium- and long-term strategies for fuel standards. Raising the necessary capital funds is the major issue in investing in new refinery units to manufacture low-sulfur diesel fuels.
- In developing fuel standards, countries should attempt to work closely with neighboring countries and harmonize

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standards where possible. This should not, however, be used as an excuse for delaying or watering down requirements, as harmonization does not mean that all countries must follow the same time schedule.

- In order to implement stricter fuel standards and make associated costs more acceptable to consumers, countries should institute more and better awareness campaigns. Such campaigns must emphasize the public health consequences of not improving fuel quality.
- Subsidies that favor fuels which produce high emissions, should be eliminated; tax policies which encourage the use of the cleanest fuels, should be adopted.

Conventional fuel improvements should clearly distinguish between primary steps and secondary steps. The former includes removing lead from gasoline, dramatically reducing sulfur levels in gasoline and diesel, and the addition of detergent additives. The latter involves reducing the Reid vapor pressure and the benzene content in gasoline.

Gasoline

The pollutants of greatest concern from gasoline-fuelled vehicles are carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NO_x), 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 and benzene level. With regard to these characteristics, the following policies are recommended:

Lead additives

Lead does not exist naturally in gasoline but must be added to it. Since the early 1970s, however, there has been a steady movement toward reducing lead in gasoline and increasingly, the complete elimination of lead. Approximately 85% of all gasoline sold

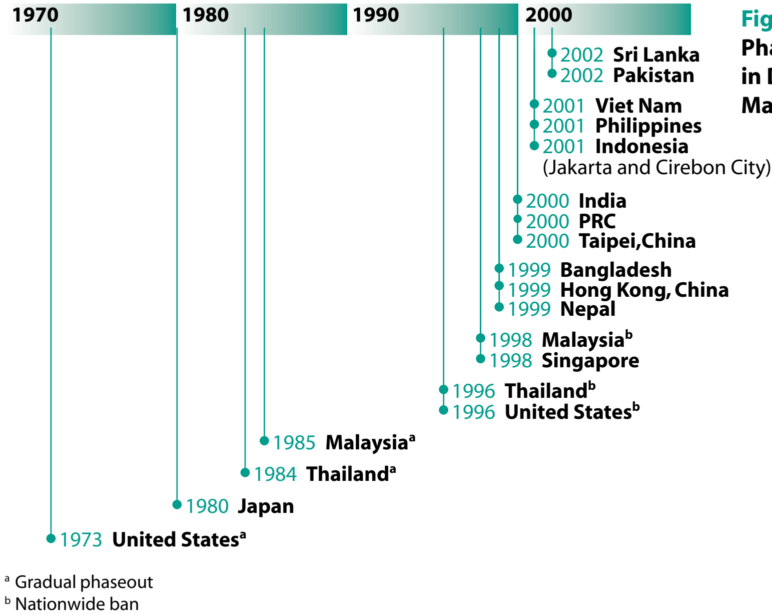

Figure 3
Phaseout of Lead in Different Markets

throughout the world is now unleaded. Figure 3 shows the timing of lead phaseout in different markets.

All modern gasoline-fuelled vehicles being produced today can operate satisfactorily on unleaded fuel, and approximately 90% of these are equipped with a catalytic converter that requires the exclusive use of lead-free fuel. There is no longer any doubt that lead is toxic and prevents the use of the clean gasoline vehicle technology that can dramatically reduce CO, HC and NO_x emissions.

- The addition of lead to gasoline should be eliminated as rapidly as possible.

Sulfur

For cars without catalytic converters, the impact of sulfur on emissions is minimal. For catalyst-equipped cars, however, the impact on CO, HC and NO_x emissions can be substantial. Based on the Auto/Oil study,[2] it appears that NO_x would decline about 3% per 100-ppm sulfur reduction for a typical catalyst-equipped car.

The situation is even more critical for advanced low-pollution catalyst vehicles. Operation on gasoline containing 330-ppm sulfur will increase exhaust volatile organic compound (VOC) and NO_x emissions from current and future new US vehicles (on average) by 40% and 150% respectively, relative to their emissions with fuel containing roughly 30-ppm sulfur.

In light of these impacts, it is not surprising that Japan has had typical gasoline sulfur levels under 30 ppm for many years. The US has also adopted a 30-ppm sulfur limit and the European Union (EU) requires gasoline with a maximum sulfur content of no more than 50 ppm in 2005 when Euro 4 standards go into effect. Even more recently, the EU has proposed to limit sulfur levels to a maximum of 10 ppm.

- In order to maximize the performance of current catalyst technology, gasoline sulfur concentrations should be reduced to a maximum of 500 ppm as soon as new vehicle standards requiring catalysts are introduced.
- Emerging advanced catalyst technologies capable of achieving very low emissions will require a maximum of 50 ppm or less. A plan for introducing such fuel quality should be adopted early in the development of a long-term vehicle pollution control strategy.

Vapor Pressure

Another important fuel parameter is vapor pressure. The vapor pressure for each season must be as low as possible in order to minimize evaporation from storage terminals and vehicles, but still sufficiently high to give safe cold starts.

An important advantage of gasoline volatility controls is that they can affect emissions from the gasoline distribution system and vehicles already in-use.

- Gasoline vapor pressure should be reduced to a maximum of 60 kilopascals whenever temperatures in excess of 20°C occur. In tropical or semi-tropical countries—such as many in Asia—this is all the time.

Benzene

Benzene is an aromatic hydrocarbon that is present as a gas in both exhaust and evaporative motor vehicle emissions. Benzene in the exhaust, expressed as a percentage of total organic gases, varies depending on the control technology (e.g., catalyst type) and the levels of benzene and other aromatics in the fuel, but is generally about 3–5%. The benzene fraction of evaporative emissions depends on the control technology and fuel composition and characteristics (e.g., benzene level and the evaporation rate), and is generally about 1%.[3] As a general rule, gasoline benzene levels should be capped at 1% as has been done in the EU.

- Benzene content should be reduced to a maximum of 1% by volume.

Oxygenates

Blending small percentages of oxygenated compounds such as ethanol, methanol, tertiary butyl alcohol, and methyl tertiary-butyl ether (MTBE) with gasoline has the effect of reducing the volumetric energy content of the fuel while improving its anti-knock performance. This makes possible a potential reduction in lead and/or harmful aromatic compounds. Assuming no change in the settings of the fuel metering system, lowering the volumetric energy content will result in a leaner air-fuel mixture, thus helping to reduce exhaust CO and HC emissions.

Impact of oxygenate used

MTBE. MTBE can be added to gasoline up to 2.7% without any increase in NO_x. There are two opposing effects that take place with the addition of oxygenates: (i) enleanment, which tends to raise NO_x, and (ii) lower flame temperatures, which tends to reduce NO_x. With MTBE levels above 2.7%, the lower flame temperature effect seems to prevail.

While the use of MTBE has been found to be very attractive from an air pollution standpoint, recent evidence in the US has shown that MTBE leaks and spills are a serious threat to drinking water. This has led to a movement to ban its future use in gasoline. The EU has not reached a similar conclusion, but rather prefers to improve the quality of underground storage tanks.

- Countries considering the use of MTBE should carefully weigh the potential air quality benefits with the potential water quality risks.

Ethanol. Ethanol can be added to gasoline at levels as high as 2.1% oxygen without significantly increasing NO_x levels, but above that point, NO_x levels can increase somewhat. For example, the US Environmental Protection Agency test data on over 100 cars indicates that oxygen levels of 2.7% or more could increase NO_x emissions by 3–4%.[4] The Auto/Oil study concluded that there was a statistically significant NO_x increase of about 5% with the addition of 10% ethanol (3.5% O_2).

Since ethanol has a higher volatility than gasoline, the base fuel volatility must be adjusted so as to prevent increased evaporative emissions. As a general rule, without adjustment, volatility will increase by about 1 pound per square inch (psi) when ethanol is added to gasoline.

- Countries considering ethanol use should carefully evaluate tailpipe CO and HC benefits versus the potential NO_x and evaporative HC increases. It should also be noted that in most countries where ethanol is used, it is highly subsidized.

Other gasoline properties

According to the Auto/Oil study, "NO_x emissions were lowered by reducing olefins, raised when T_{90} was reduced, and only marginally increased when aromatics were lowered."[5] In general, reducing aromatics and T_{90}, the temperature at which 90% of gasoline evaporates, caused statistically-significant reductions in exhaust mass nonmethane hydrocarbons (NMHC) and CO emissions. Reducing the olefins increased exhaust mass NMHC emissions, however "the ozone forming potential" of the total vehicle emissions was reduced.[6]

With regard to toxics, the reduction of aromatics from 45% to 20% caused a 42% reduction in benzene but a 23% increase in formaldehyde, a 20% increase in acetaldehyde and about a 10% increase in 1,3-Butadiene.[7] Reducing olefins from 20% to 5% lowered 1,3-Butadiene by 31% but had insignificant impacts on other toxics. Lowering the T_{90} from 360 to 280°F resulted in statistically-significant reductions in benzene, 1,3-Butadiene (37%), formaldehyde (27%) and acetaldehyde (23%).

- To the extent that the long-term vehicle emissions standards strategy is to adopt Euro 4 standards for light duty vehicles, the European gasoline standards (see Table 1) should be adopted in the same time frame.
- Detergent or engine deposit control additives are critically important with modern engines and should be mandatory as well.

Table 1
Gasoline Specifications in Asia and Europe

	Lead	Sulfur ppm	Benzene % v/v, max	Aromatics %	Olefins %	Oxygen % m/m, max	RVP summer kPa, max
Linked to Euro 3 Vehicle Standards Effective 2000	Lead free	150	1.0	42	18	2.7	60
Linked to Euro 4 Vehicle Standards Effective 2005	Lead free	50	1.0	35	18	2.7	60
Bangladesh	Lead free	1000	—	—	—	—	0.7 kg/m²
Cambodia	0.15 g/l	—	3.5	—	—	—	—
Hong Kong, China	Lead free	150	1	42	18	2.7	60
India	Lead free	1000[a]	5[b]	—	—	2.7	35-60
Indonesia	0.30 g/l	2000	—	—	—	2.0 (premix)	62
Japan	Lead free	100	1	—	—	—	78
Malaysia	Lead free	1500	5	40	18	—	70
Philippines	Lead free	—	2	35	—	—	—
PRC	Lead free	1000	2.5	40	35	—	74
Singapore	Lead free	—	—	—	—	—	—
Sri Lanka	Lead free	1000	4	45	—	2.7	35-60
Taipei,China	Lead free	180	1	—	—	2.0	8.9 psi
Thailand	Lead free	500	3%	35	—	1-2%	—
Viet Nam	Lead free	5000-10000	5	—	—	—	—

g/l = gram per liter, kg/m^2 = kilogram per square meter, kPa = kilopascal, ppm = parts per million, %m/m = percent by mass, %v/v = percent by volume, psi = pound per square inch, RVP = Reid vapor pressure

[a] In Delhi, Mumbai, Kolkata and Chennai sulfur levels are 500 ppm

[b] Benzene – 3% in metros and 1% in National Capital Region