STUDY ON DEVELOPING APPROPRIATE UNLEADED GASOLINE SPECIFICATION FOR INDONESIA (2000-2010)

by
Rasdinal Ibrahim, Adiwar, and **Mardono**

ABSTRACT

Automotive fuels are significant sources of air pollution in most metropolitan areas. Motor gasoline is responsible for emission of carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NOx), sulfur oxides (SOx) which all have adverse impacts on the environment and public health.

In line with the implementation of Blue Sky Program, revision of the current gasoline specification needs be taken to improve the quality of Indonesia's gasoline to meet vehicle engine technology and environmental requirement with the global fuel specification harmonization as formulated in the World Wide Fuel Charter as reference.

This study on developing of appropriate unleaded gasoline specification in Indonesia consists of examination of the key properties that influence the emissions, status and trend of current gasoline specification, comparison of Indonesia's gasoline specification with other countries and recommendation of the new unleaded gasoline specification options that match the implementation of Blue Sky Program in Indonesia and the scenario for its implementation.

I. INTRODUCTION

Automotive fuels are significant sources of air pollution in most metropolitan areas. Vehicles which are running on the gasoline are responsible for emission of carbon monoxide (CO), volatile organic compounds (VOC), nitrogen oxides (NOx), sulfur oxides (SOx), which all have adverse impacts on the environment and public health.

In favor of managing air pollution, the Indonesian government has decreed the Blue Sky Program in 1996, which impels a quick action to reduce air pollution. In line with this program, revision of the current gasoline specifications needs be taken to improve the quality of Indonesia's gasoline to meet the global fuel specification harmonization for environmental requirement.

Basically, gasoline must meet the technical and engine requirements of their intended uses. In that sense, the technical specifications of gasoline in different countries are similar. The national specification, however, may vary slightly because of the different conditions existing in each country, such as fleet composition, crude oil availability, processing facilities, government policies with regard to distribution, safety and environment and many other considerations.

Gasoline specifications in Indonesia are decreed by the government c.q. Directorate General of Oil and Gas, Department of Energy and Mineral Resources. In determining the fuel specifications some factors were considered such as engine technology development, refining capability, environmental aspect and economic factor.

This study aims at developing of new fuel specification options and recommending an appropriate specification to match the implementation of Blue Sky Program in Indonesia. For this purpose a broad review will be presented on gasoline specification and key properties that influence the emissions, status and trend of Indonesia's gasoline specification, comparison of Indonesia's gasoline specification with other countries.

II. GASOLINE SPECIFICATION AND THE PRESSURE FOR CHANGES

Automotive gasoline manufactured and marketed must meet the required legal specifications. National or other legally enforceable specifications represent the minimum quality that must be supplied, which implied

that vehicles should run satisfactorily on such a quality and meet legislative requirement in terms of emissions and fuel economy.

Gasoline qualities have always been a dynamic concept; many different pressures force the changes such as environment considerations, vehicle technology advances, crude oil prices and security of supply. Environmental pressure will continue to be the major factor in influencing gasoline quality. For gasoline, in the countries where organic lead compound is still being used as additive, fiscal incentives are generally used to encourage the demise of leaded gasoline.

Phasing out of lead from gasoline has become important, not only to eliminate the hazardous lead compound, but also enable the use of catalytic converter on vehicle to reduce such emissions as CO, HC, NOx, and SOx as well.

More severe reforming process applied in gasoline manufacture will help in meeting the octane quality, but at the expense of yield and the production of high levels of aromatics which themselves have environmental disadvantages. Benzene as a toxic emission is found in vapor emissions, as well as in the exhaust, and other toxic emissions such as 1,3 butadiene also a constituent of olefin content, formaldehyde, acetaldehyde, and polycyclic organic matter are primarily products of combustion. Thus, benzene, aromatic and olefin contents are specified in the advanced countries, which can afford to impose them.

VOCs (volatile organic compounds) comprise the mass of organic compounds that contribute to ground-level ozone formation. The VOCs include oxygenated organic compounds and all hydrocarbons except ethane and methane. About 37% of the VOCs in the atmosphere came from exhaust hydrocarbon, evaporative losses from vehicle contribute about 28%, running loss 32% and losses during refueling about 3% (UOP, 1994).

Automotive technology changes, on the other hand, also influence future gasoline specification, including wider use of continuously variable transmission system (CVTs), improved fuel injector, engine breathing, engine management system aided by sensor, lower drag coefficient, and progressive introduction of Low emission Vehicle (LEV), Ultra-Low Emission Vehicle (ULEV) and Zero Emission Vehicle (ZEV).

III. KEY PROPERTIES OF GASOLINE THAT INFLUENCE THE EMISSIONS

Gasoline is essentially a complex mixture of hydrocarbons distilling at about 30°C to 210°C and designed as fuel for spark ignition engines. It consists of some 200-300 compounds in the range C_4 to C_{11} hydrocarbons. Gasoline is made of blends of hydrocarbons derived from fractional distillation of crude oil and further conversion processes that increase either amount or quality of gasoline. Some key properties of gasoline, which give an impact for the emission, are discussed below.

A. *Lead Content*

The majority of airborne lead originates from alkyl lead compound introduced into gasoline as an antiknock agent since 1922. Lead is a cumulative poison, which causes a hazard to individuals with chronic disease or subtle changes in metabolic function and damage to the organ and tissue, particularly in children.

Phasing out of lead from gasoline is becoming more important, not only to eliminate the hazardous lead compound, but also to enable the use of catalytic converter on vehicles to reduce such emissions as CO, HC, NOx and SOx.

B. *Volatility*

Volatility is the main property of gasoline, which affects the performance of the engine; driveability, ease of starting, rate of warm-up, vapor lock and crankcase dilution. The gasoline must be sufficiently volatile to give easy starting, rapid warm-up and adequate vaporization for proper distribution between cylinders. On the other hand it must not be too volatile that the vapor losses from the tank are excessive, or that vapor may be formed within fuel line thus impeding the flow of fuel to the carburetor by vapor lock.

The volatility characteristic of gasoline is measured by means of two standard test methods, i.e. ASTM Distillation and Reid Vapor Pressure (RVP). Gasoline containing significant amounts of low boiling point components tends to give high VOC emissions. High boiling components are more difficult to vaporize especially in cold engine; making complete combustion more difficult. Thus, placing limits on the distillation profile can lower VOC emissions. Decreasing the vapor pressure of gasoline reduces evaporative VOC emission and reduces ozone formation. For example reducing RVP from 8.7 to 8.0 psi, by adding MTBE will reduce VOC by 16% (UOP, 1994).

C. *Sulfur Content*

Sulfur in the fuel becomes sulfur oxides in the exhaust, which temporarily poison the three-way catalyst in the catalytic converter. Reducing gasoline's sulfur con

tent will increase catalytic converter efficiency and decrease VOC, CO, NOx and toxic emission.

Reducing sulfur from 339 to 288 ppm by adding MTBE will reduce VOC emission by about 1%, NOx emission by about 1.4% and toxic emission (UOP, 1994). Reducing sulfur content also reduces direct emission of sulfur dioxides and sulfate, but gasoline engine is not a major source of these pollutants.

D. *Aromatics and Benzene Contents*

Aromatics are molecules that contain at least one benzene ring. In general, aromatics are good octane component of gasoline. Aromatic content of gasoline can increase engine deposits and increase tailpipe emissions such as HC, CO and NOx. Combustion of aromatics can lead to the formation of carcinogenic benzene in exhaust gas and increase combustion chamber deposits, which can increase tailpipe emission.

Decreasing the total aromatics content of gasoline decreases the amount of benzene in exhaust VOC emissions, so that decreasing aromatic content has the most impact on reducing toxic emissions. In order to meet octane specification, unleaded gasoline normally contains about 30–50% aromatic hydrocarbon. Reducing the content of aromatic hydrocarbon in gasoline tends to reduce NOx emission, exhaust reactivity and benzene emission. Decreasing aromatics also tends to reduce CO and total exhaust VOC emissions, but the effects are variable and complex. A study by US Environment Protection Agency (US EPA) indicated that reduction of aromatic content from 32.0 to 26.3% vol. by adding MTBE would cause reduction of about 1% VOC and 0.9% NOx emissions (UOP, 1994).

(e) Olefin Content

Olefins are unsaturated hydrocarbons and, in many cases, are also good octane components of gasoline. However olefins in gasoline can lead to deposit formation and increase emissions of reactive hydrocarbons (i.e. ozone-forming) and toxic compounds. Olefins are thermally unstable and may lead to gum formation and deposits in an engine's intake system. Olefins are more reactive than paraffins and naphthenes for ozone formation.

Reducing olefin content from 9.2 to 7.8% vol. by adding MTBE reduces about 0.45% of NOx emissions (UOP, 1994). The effect on ozone-forming potential was clearly demonstrated by the US Auto/Oil Program, which concluded that reducing total olefins from 20% to 5% would significantly decrease ozone forming potential by 20-29% (ACEA, Alliance, EMA, JAMA, 2000).

(f) Octane Number

Octane number is a measure of gasoline's antiknock performance, its resistance to detonation and knocking as it burns in the combustion chamber. Knock reduces engine power output, and severe or prolonged knock will likely damage the pistons and overheat the engine. Higher-octane fuels are more resistance to knocking, and can thus be used in engines with higher compression ratio.

There are two test methods of octane number measurement, Research Octane Number (RON) and Motor Octane Number (MON). RON correlates best with low speed mild knocking condition and MON correlates best with high-speed high temperature knocking conditions, and with part throttle operation. The difference between RON and MON is called the sensitivity of the fuel.

IV. STATUS AND TREND OF INDONESIA'S FUEL SPECIFICATIONS

As mentioned above, basically fuel specifications reflect the compromise between four different interests and considerations, namely those of the consumers, producers, general public, and the government. The consumers would like to have fuel that conforms to their engines at a reasonable price. The producers would try to satisfy the consumer need at reasonable profit. The public in general insists that safety, health, and clean environment be ensured, while the government, as guardian of long-term national interest would express its policy with regulatory power.

Fuel specifications in Indonesia are decreed by the government c.q. Directorate General of Oil and Gas, Department of Energy and Mineral Resources. In determining fuel specifications some factors are considered, such as engine technology development, refining capability, environment and economic factor. At present there are four grades of motor gasoline marketed in Indonesia, namely:

- Premium 88, a leaded gasoline (0.3 gr Pb/l, 88 RON), market share of about 95%vol.
- Premix, a leaded gasoline (0.3 gr Pb/l, 94 RON) with a market share of 3.1%vol.
- Super TT, an unleaded gasoline (95 RON) with a market share of 0.4%vol.
- BB2L, an unleaded gasoline (80-85 RON) for two-stroke engine, share of 1% vol.

Table 1
Indonesia's Current Gasoline Specification (Year 2000)

Properties			Gasoline				Test method
			BB2L	Premium	Premix.	Super TT	
Octane Number:							
Research (RON)		min	80 – 85	88	94	95	ASTM D - 2699
Volatility:							
Distillation							ASTM D - 86
10%	°C	max	74				
50%	°C	min-max	88-125				
90%	°C	max	180				
FBP	°C	max	205				
Residue	%vol	max	2				
RVP @100F	kPa	max	62				ASTM D - 323
Composition:							
Lead Content	gr Pb/l	max	0,013	0,3	0,3	0,005	ASTM D - 3341 /3237
Sulfur Content	%wt	max	0,2	0,2	0,2	0,2	ASTM D - 1266
MTBE/oxygenates	%vol	max	-	-	11	10	
Other Parameters:							
Density @ 15? C	kg/m3						
Copper corrosion	No.	max	1	1	1	1	ASTM D - 130
Mercaptan S	%m/m	max	0,002	0,002	0,002	0,002	ASTM D - 3227
Doctor Test			neg	neg	neg	neg	IP 30
Oxidation Stability	minute	min	240	240	240	240	ASTM D - 525
Existent Gum	mg/100ml	max	4	4	4	4	ASTM D - 381
Colour			marketable	yellow	red	without dye	

The current Indonesia gasoline specifications are tabulated in Table 1. The specifications of the four types of Indonesia's gasoline differ only in their lead content and octane number. The other properties, such as distillation, RVP, sulfur content etc. is in the same level of specification. Several parameters, such as aromatic, benzene, and olefin contents that have impact on emissions are not specified yet in the current Indonesia gasoline specifications.

Lead phase out program of Indonesia's gasoline has been carried out step by step, starting with a single-grade gasoline policy in 1990, when Super-98 with TEL 3.0 cc/USG (0.9 gr Pb/l) was substituted by Premix with TEL 1.5 cc/USG (0.45 gr Pb/l). At that time lead content of Premium was reduced from 2.5 cc/USG (0.75 gr Pb/l) to 1.5 cc/USG (0.45/ gr Pb/l). Phase down of lead was continued in 1997/98 by reducing lead content of Premium from 1.5 cc/USG (0.45 gr Pb/l) to 1.0 cc/USG (0.30 gr Pb/l).

Unleaded gasoline was introduced first in Indonesia in 1995, by launching of Super-TT, with 95 RON minimum. However, due to the limited refinery capability and the price policy, the market share of Super-TT is still very low. A low RON (80-85) unleaded BB2L was introduced in 1998 and is meant for two stroke motorcycles.

In line with the Blue Sky Program, which is launched by government and the need for a clean environment, Indonesia is projected to completely perform phase out of lead in gasoline by 2003 after completing the refinery reconfiguration, and for Jabotabek area (Jakarta environs) only unleaded gasoline has been supplied from Balongan Refinery since 1 July 2001.

Table 2
Main Gasoline Specification in ASEAN Countries

Properties			Singapore		Malaysia		Thailand		Philippines		Indonesia			
			UL Prem.	UL Reg.	UL Prem.	Reg.	UL Prem.	UL Reg.	Prem	UL Prem.	BB2L	Prem.	Premix	Super TT
Octane Number:														
Research (RON)		min	98	92	97	92	95	87	93	93	80-85	88	94	95
Motor (MON)		min					84	76						
(RON+MON)/2		min												
Volatility:														
RVP @100F	kPa	max	70		70		62		85		62			
Composition:														
Lead	gr Pb/l	max	0.005	0.005	0.013	0.15	0.013		0.15	0.013	0.013	0.3	0.3	0.005
Sulfur Content	%wt	max	0.2	0.2	0.15	0.15	0.1		0.2	0.1	0.2	0.2	0.2	0.2
Aromatic Content	%vol	max					35		55					
Benzene	%vol	max					3.5		5					
Olefin	%vol	max	15.0				11		10				11	10

Tabel 3
Main Gasoline Specification in East Asian Countries

Properties			China			South Korea		Taiwan			Japan	
			Premium	Reguler	UL Reg	UL Prem.	UL Reg.	Premium	UL Prem.	UL Reg.	Premium	Reg
Octane Number:												
Research (RON)		min	97	91	91	96	91	95	95	92	96	89
Motor (MON)		min	92	87	87	87	83					
(RON+MON)/2												
Volatility:												
RVP @100F	kPa	max	Summer 62			45 - 85		69			Summer 44 - 78	
Composition:												
Lead	gr/l	max	0.15	0.13	0.026	0.013		0.08	0.015	0.015	Unleaded	
Sulfur Content	%m/m		0.1	0.1	0.1	0.01		0.1	0.1	0.1	0.01	
Aromatic Content	%vol	max				50.0					5.0	
Benzene	%vol	max				5.0						
Olefin	%vol	max										

V. INDONESIA'S GASOLINE SPECIFICATION AS COMPARED TO OTHER COUNTRIES

In developing Indonesia's fuel specifications that meet the global harmonization on fuel specifications for implementation of the Blue Sky Program, comparative studies on fuel specifications with those of other countries in the world should be carried out.

Comparison is made particularly with those of neighboring countries in Southeast Asia/ASEAN particularly Malaysia, Singapore, Thailand and Philippines, which have similar weather condition and environment, and with

a view of enabling product exchange between the countries. The main gasoline specifications of Singapore, Malaysia, Thailand, Philippines and Indonesia are presented in Table 2. It can be seen that the countries of ASEAN two grades of gasoline are available, except Indonesia which has four grades of gasoline.

Comparison is also made with the new industrial countries of East Asia such as Japan, South Korea, China and Taiwan. Table 3 shows the main gasoline specifications of these countries. From Table 3, it is observed that China, South Korea, Taiwan and Japan have two grades of gasoline, i.e. regular and premium grade. South Korea and Taiwan specify the lowest sulfur content in Asia (0.01 m/m).

For study horizon a comparison is also made with advanced countries of the world, which have implemented stringent emissions control, such as Europe, USA, and California in particular. Table 4 shows the main gasoline specifications of Euro I, II, II, US EPA and CARB (California Air Resource Board). Here it can be seen that both US EPA and CARB specification do not specify the octane number of gasoline due to localized altitude sensitivity.

In this study the World-Wide Fuel Charter (WWFC) gasoline specification (Table 5), which gave recommendation on fuel specifications from the point of engine requirement and environmental standards, is used as a reference for developing gasoline specification in the future. The main properties in Indonesia's gasoline specification compared to other countries specifications are described below.

A. *Lead Content*

From Table 2 and Table 3 it can be seen that some of the Asian countries namely Malaysia, Philippines, China, Taiwan, as well as Indonesia are still using both leaded and unleaded gasoline in their gasoline specifications. Singapore, Thailand, South Korea and Japan on the otherhand, have totally phased-out lead from their gasoline.

In the Southeast Asia region, Malaysia led the introduction of unleaded gasoline in 1990, followed by Singapore and Thailand in 1991 respectively. Thailand successfully completed the phase out of leaded gasoline on 1 January 1996. Philippines introduced unleaded gasoline in 1993 and Indonesia followed in August 1995. To compensate for the elimination of lead from gasoline, Asian countries turned to use oxygenated compounds, particularly methyl tertiary butyl ether (MTBE) at the level of 10-15% as octane booster.

It can be seen that Indonesia's gasoline specification, specifies the highest lead content of leaded gasoline (0.3 gr Pb/l) in Asia. But actually in the market, the lead content of Indonesia gasoline is not so high. The typical

Tabel 4
Main Gasoline Specification in Europe, US EPA and California

Properties			Europe		US EPA		CALIFORNIA, CARB	
			Euro I, II	Euro III	N. Generic	N. Premium	On Average	Per gallon
Octane Number:								
Research (RON)		min	95	95				
Motor (MON)		min	85	85				
(RON+MON)/2		min			87	93*		
Volatility:								
RVP @100F	kPa (Psi)		35 - 100	35 - 100	45	62		7.0
Composition:								
Lead	gr Pb/l	max	0.013	0.005	-		-	
Sulfur Content	%wt (ppm)		0.05	0.015	0.034	0.016	(30)	(40)
Aromatic Content	%vol	max		42	31.1	35.9	22.0	25.0
Benzene	%vol	max	5.0	1.0	-	-	0.8	1.0
Olefin	%vol	max		18	11.4	6.5	4.0	6.0

Table 5
World Wide Fuel Charter Gasoline Specification

Properties				Category I	Category II	Category III	Category IV	Methode
91 RON	Research Octane Number		min	91.0	91.0	91.0	91.0	ASTM D - 2699 - 86
	Motor Octane Number		min	82.0	82.5	82.5	82.5	ASTM D - 2700 - 86
95 RON	Research Octane Number		min	95.0	95.0	95.0	95.0	ASTM D - 2699 - 86
	Motor Octane Number		min	85.0	85.0	85.0	85.0	ASTM D - 2700 - 86
98 RON	Research Octane Number		Min	98.0	98.0	98.0	98.0	ASTM D - 2699 - 86
	Motor Octane Number		min	88.0	88.0	88.0	88.0	ASTM D - 2700 - 86
Oxidation Stability		minute	min	360	480	480	480	ASTM D - 525 – 99a
Sulfur Content		% m/m	max	0.10	0.02	0.003	sulfur free*	ASTM D - 2622 - 98
Lead Content		g/l	max	0.013	ND	ND	ND	ASTM D - 3237 - 97
Phosphorus Content		mg/l		-	ND	ND	ND	ASTM D - 3231 - 99
Manganese Content		mg/l		-	ND	ND	ND	ASTM D - 3831 - 94
Silicon		mg/kg		-	ND	ND	ND	
Oxygen Content		% m/m	max	2.7	2.7	2.7	2.7	ASTM D - 4815 – 94a
Olefins Content		% v/v		-	20.0	10.0	10.0	ASTM D - 1319 - 99
Aromatics Content		% v/v	max	50.0	40.0	35.0	35.0	ASTM D - 1319 - 99
Benzene Content		% v/v	max	5.0	2.5	1.0	1.0	ASTM D - 4420 - 94
Volatility								
Sedimen		mg/l	max	-	1	1	1	ASTM D - 5452 - 97
Unwashed gums		mg/100ml	max	70	70	30	30	ASTM D - 381 – 99
Washed gums		mg/100ml	max	5	5	5	5	ASTM D - 381 – 99
Density		kg/m^3	min-max	715 - 780	715 - 770	715 – 770	715 - 770	ASTM D - 4052 - 96
Copper corrosion		merit		1	1	1	1	ASTM D - 130 – 94
Appearance				CB	CB	CB	CB	
Carburettor cleanliness		merit	min	8.0	-	-	-	
Fuel Injector cleanliness		% flow loss	max	10	5	5	5	ASTM D - 5598 – 95a
Intake valve sticking		pass/fail		-	pass	Pass	pass	
Intake valve cleanliness I		merit	min	9.0	-	-	-	
Intake valve cleanliness II								
- Method 1 (CEC F-05-A-93) or		avg.mg/valve	max	-	50	30	30	
- Method 2 (ASTM D - 5500) or		avg.mg/valve	max	-	100	50	50	ASTM D - 5500 - 98
- Method 3 (ASTM D - 6201)		avg.mg/valve	max	-	90	50	50	ASTM D - 6201 - 99
Combustion chamber deposits								
- Method 1 (ASTM D - 6201) or		%	max	-	140	140	140	ASTM D - 6201 - 99
- Method 2 (CEC F-20-A-98)		mg/engine	max	-	3500	2500	2500	

ND : Non Detectable
CB : Clear and Bright
*) Probably 5 – 10 ppm max

Table 6
Recommended Indonesia's Gasoline Specification in Comparison to WWFC Category 1

Properties			Year 2000 (existing)			Year 2003			Year 2005		Year 2010		WWFC	Method
			Premium	Premix	Super-TT	Premium	Prem-TT *)	Superr-TT	Prem-TT	Super-TT	Prem-TT	Super-TT	Category 1	
Octane Number :														
Research (RON)			88	94	95	88	88	95	91	95	91	95	91	ASTM D - 2699
Volatility :														
10%	°C	max	74			74			74		74		70	ASTM D - 86
50%	°C		88 – 125			88 - 125			88 - 125		88 - 125		77- 110	
90%	°C	max	180			180			180		180		130 - 190	
FBP	°C	max	205			205			205		205		215	
RVP @ 100F	kPa(Psi)	max	62 (9)			62 (9)			62 (9)		54 (7.8)		45 - 60	ASTM D - 323
Composition :														
Lead	gr/l	max	0.30		0.005	0.3	0.013	0.005	0.005		Undetectable		0.013	ASTM D - 3237
Sulfur Content	%wt	max	0.20		0.20	0.20	0.10	0.10	0.10		0.02		0.10	ASTM D - 1266
Aromatic Content	%vol	max					50.0		50.0		35.0		50.0	ASTM D - 1319
Benzene	%vol	max					5.0		5.0		2.0		5.0	ASTM D - 4420
MTBE (oxygenates)	%vol	max			10									
Other Parameters :														
Copper Corrosion	No	max	1			1			1		1		1	ASTM D - 130
Mercaptan S	%m/m	max	0.002			0.002			0.002		0.002		-	ASTM D - 1266
Doctor Test			Neg			Neg			Neg		Neg		-	IP – 30
Oxidation Stability	minute	min	240			240			360		360		360	ASTM D - 525
Existent Gum	mg/100l	max	4			4			4		4		5	ASTM D - 389

*) Available in Jabotabek Area since 1 Juli 2001

gasoline (Premium type) from Balongan refinery has low lead at range of 0.02 to 0.21 grPb/l or about 0.09 grPb/l in average (Report of Balongan Refinery April – June 1999).

Nevertheless, this clearly suggests that, Indonesia must intensify lead phase-out efforts from the gasoline. World-Wide Fuel Charter specification allows 0.013 g Pb/l, without intentional addition for Category 1 to accommodate some contamination by small amounts of lead that may occur in the distribution system such as tank, pipe, etc. This is the general concentration of lead, which may be detected, in unleaded gasoline.

B. *Sulfur Content*

Compared to other Asian countries (China, South Korea, Taiwan and Japan), Indonesia's gasoline sulfur content specification is the highest. Japan and Korea specify 0.01% m/m maximum of sulfur content, the lowest specification in Asian countries.

In the current Indonesia's gasoline, sulfur content specification is specify 0.2% m/m, although the sulfur content of gasoline in the market is not so high; for example typical gasoline from Balongan refinery has low sulfur content at about 0.02% m/m in average (Report of Balongan Refinery April – June 1999).

C. *Aromatic, Benzene, and Olefin Contents*

Most of Asian countries including Indonesia have not specified yet the aromatic, benzene and olefin contents in their gasoline specification. Some of Asian countries such as Thailand, Philippines and Japan specify benzene content in their gasoline specification within range of 3.4–5.0% vol. maximum.

Euro I and II specify benzene content at 5.0% vol. meanwhile Euro III specifies benzene content at 1.0% vol. maximum while US CARB specification is the lowest one.

Only US-EPA National and CARB specify the olefin content of gasoline, namely within range of 4.0–11.4% vol. The lowest specification of aromatic, benzene and olefin contents, in gasoline is observed in CARB specifications, which set it at 22% and 25% vol. maximum limit for aromatic content, 0.8% and 1.0% vol. for benzene, 4.0% and 6.0% vol. for olefin.

D. *Octane Number*

All Asian countries such as China, Taiwan, South Korea, and Japan specify two grades of gasoline, which are regular grade with octane level of 91 to 92 RON (except Japan which has a regular grade ULG of 89 RON), and premium grade with octane level of 95 to 97 RON. Tables 2, 3 and 4 show the RON specifications of Southeast Asia, East Asia and Europe respectively and Table 5 shows the WWFC specification Categories 1, 2, 3 and 4.

Gasoline used in most Southeast Asian countries have two grades of octane level, a regular grade of 87 – 92 RON, with Thailand having a regular grade ULG of 87 RON, and a premium grade of 93 – 98 RON. On the other hand, Indonesia has seem to have too many, four grades of gasoline, namely BB2L of 80-85 RON, Premium of 88 RON, Premix of 94 RON and Super-TT of 98 RON.

E. *WWFC Gasoline Specification*

The world car manufacturer association of USA (AAMA/EMA), European (ACEA) and Japan (JAMA), supported by those of Canada, China, Korea, and South Africa developed a World-Wide Fuel Charter in 1998 and updated in 2000 in their effort of global harmonization of fuel specifications. The objective is to develop common, world-wide recommendation for quality fuels taking into consideration the customer requirements, vehicle emission technology and environment.

The four categories of gasoline specifications of WWFC are presented in Table 5. The WWFC, which gave recommendation on fuel specifications from the point of engine requirement and environmental standards, is used as a reference in developing of Indonesia's gasoline specification in the future.

From the emission control point of view, Category 1 is the simplest one, with no or minimal requirement for emission control, increasing of requirement for emission control is shown by increasing the category number.

VI. RECOMMENDATION FOR UNLEADED GASOLINE SPECIFICATIONS IN INDONESIA

Based upon comparative study on the fuel specifications to other countries above, information of octane requirement of vehicles population in Indonesia, and consideration of WWFC specification, the following recommendations are presented for developing the new unleaded gasoline specification for Indonesia:

Considering the toxicity of lead compound, and its poisonous to catalytic converter, lead should thus be phased out from Indonesia's gasoline. WWFC Category 1 allows 0.013 g Pb/l for unleaded gasoline without in

tentional addition to accommodate contamination by a small amount of residual lead in the distribution system. This level should have little impact on catalyst performance.

Regarding the high sulfur content stated in Indonesia's gasoline specification compared to other countries that has impact on emission and reducing effect on catalytic converter efficiency, sulfur content in the specification should be reduced from 0.2% m/m to 0.1% m/m to meet WWFC Category 1. This specification is recommended for national specification in the first stage (2003), and will be supplied for Jabotabek area in the year 2001, due to the nearby Balongan refinery capability to produce lower sulfur content unleaded gasoline.

The octane level should meet octane requirements of vehicles population in Indonesia with consideration of the future octane requirement of vehicle established by the world car manufacturers defined by WWFC specification (i.e. 91 RON min.). Thus 91 RON of gasoline is proposed as regular grade of Indonesia's gasoline to satisfy more than 90% of car. However, due to the current limited refining capabilities, that need 3 or 4 years to built HOMC plants, 88 RON unleaded gasoline which satisfies about 60% of vehicle population can be established first at 2003 for national specification. For Jabotabek area, which is supplied by Balongan refinery which has the capability to produce 88 RON unleaded gasoline, the 88 RON unleaded gasoline will be implemented in the year 2001.

To meet WWFC specification that specify low-grade and high-grade octane level of gasoline, and in consideration of other countries gasoline specifications, two grades of Indonesia gasoline are proposed, i.e. 88 RON in 2003 and 91 RON in 2005 as Regular grade, and 95 RON as Premium grade for National Specification. For Jabotabek area, 88 RON will be supplied in July 2001 and 91 RON in 2003 as Regular grade, and 95 RON as Premium grade.

Aromatic, benzene and olefin contents can be considered for being specified in Indonesia's gasoline in 2005. The 2010 recommended gasoline specification is proposed to achieve cleaner gasoline for the clean environment. The specification is based on the performance and environment requirement of the WWFC Category 3 which consists of three grades of gasoline i.e. 91 RON, 95 RON and 98 RON, and lead content is undetectable and sulfur content of 0,003% etc.

The propose scenario of development of Indonesia's gasoline specification in the next future 2000 to 2010, and recommended new unleaded gasoline specification for Indonesia is presented in Table 6.

VII. CONCLUSION

1. In line with the implication of Blue Sky Program Indonesia, some revision of the current gasoline specification need be taken to develop appropriate unleaded gasoline specification, by improving the quality of gasoline that meet the global fuel specification harmonization for environmental requirement.

2. The unleaded gasoline specifications have been developed based on a comparative study on the fuel specifications to other countries, octane requirement of vehicles population in Indonesia, in a scenario that takes into account the capability of PERTAMINA Refinery to produce it and economic consideration.

3. Due to the current limitation of refining capabilities, and the need of 3 or 4 years to built HOMC plants, the 88 RON unleaded gasoline which satisfies about 60% of vehicle population can be established first at 2003 for national specification, while for Jabotabek area which is supplied by Balongan refinery the 88 RON unleaded gasoline will be implemented in the year 2001.

REFERENCES

1. AAMA, ACEA, JAMA, 2000, "World-wide Fuel Charter", December.
2. Jasjfi E., Nasution A.S., 1997/1998, "The Progress Tower Cleaner Transportation Fuels in ASEAN", Lemigas Scientific Contributions 2.
3. Keith Owen, Trevor Coley, 1995, "Automotive Fuels Reference Book", SAE, Inc., Warrendale.
4. UOP, 1998, "Diesel Fuel Specifications and Demand for the 21st Century", Des Plaines Illinois.
5. UOP, 1994, "The Challenge of Reformulated Gasoline, The 1990 Clean Air Act Amendments" Des Plaines Illinois.
6. US EPA, 1999, "Implementers Guide to Phasing Out Lead in Gasoline" Environmental Pollution Prevention Project Hagler Bailly Services, Inc, Alexandria.
7. Weissmann, J., 1972, "Fuels for Internal Combustion Engines and Furnaces", Lembaga Minyak dan Gas Bumi, Jakarta. •