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Archives of Applied Science Research, 2015, 7 (10):65-75  
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## Evaluation of Sudanese gasoline produced from Nile blend crude oils for improvement

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### ABSTRACT

*In this study gasoline samples were collected from Khartoum refinery from Fluid Catalytic Cracking unit (FCC), the Reformate Gasoline unit (RFG) and finished product. The Oxygenated were prepared from the finished gasoline plus the ethanol in a different blend ratios, such as 5 % of ethanol (E5), 7.8 % of ethanol (E7.8), and 10 % of ethanol (E10). The analysis carried out on the gasoline samples and the blends. The analysis done in this study is the main properties of gasoline that have direct impact on the environment, etc. Gas chromatography was used to analyze the olefins and aromatics hydrocarbon groups and benzene component. Octane number, Reid Vapor Pressure (RVP) and sulphur content were measured, etc. The result shows the aromatics content of the Sudanese gasoline produced from Khartoum refinery was of a good quality worldwide, especially when it compared with the British, the World Wide Fuel Charter (WWFC), the Emirate, and the Indian standard specifications. Which is a better environmental outcome will be achieved. Also the current Sudanese gasoline has an intermediate value of benzene, olefins and sulphur contents when it compared with the British and the WWFC specifications as a high standard, and the Emirate and the Indian specifications as a low standard. On the present study the octane number of the current Sudanese gasoline produced at the Khartoum refinery is found to be low when it is compared with the WWFC and the British standard specifications, also the existing gum of the Sudanese gasoline is within the international specification. The result present of study shows that the adding of the ethanol to the gasoline obtained a greatest improvement in octane number, e.g. the use of 10% ethanol will increase the octane number to 3.6 points. Also there are noticeably decreasing in aromatics, benzene and sulphur contents, and there is a major reduction of olefins substantially with the ethanol volume, which is to somewhat a better environmental outcome will be achieved. The RVP of the blends E5, E7.8 & E10, are within the range of the RVP of the Sudanese standard specifications.*

### INTRODUCTION

#### The petroleum products from crude oil

Crude oil contains hundreds of different types of hydrocarbons all mixed together, which is considered as a complex mixture of many different components. The separation of these components into useable products by heating the crude oil and the different components are pulled out by their vaporization temperatures is known as refining. The refining is started by the fractional Column Distillation Unit (CDU) and the Vacuum Distillation Column Unit (VDU).

The resulting fractions are either sent directly to the product pools or processed further to make them into more valuable products.

**Gasoline**

The most important refinery product is motor gasoline, which is a blend of hydrocarbons with boiling ranges from ambient temperatures to about 400 °F. The important qualities for gasoline are octane number (antiknock), volatility (starting and vapor lock), and vapor pressure. Additives are often used to enhance performance and provide protection against oxidation and rust formation (Mahmoud Ahmed R. 2003)

ASTMD 4814, Specification for Automotive Spark-ignition Engine Fuel, defines gasoline as a volatile mixture of liquid hydrocarbons, containing small amounts of additives,( R.L.Furey,et al. 1993)

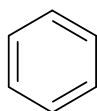
According to ( James G. Speight, 1980) gasoline is essentially a complex mixture of hydrocarbons that boil below 180 °C (355 °F), or at most below 200 °C (390°F) and the hydrocarbons of gasoline in this boiling range fall into three general types:

Paraffin's which include cycloparaffins and isoparaffins

CH<sub>3</sub>-CH<sub>2</sub>-CH<sub>2</sub>- CH<sub>2</sub>-CH<sub>2</sub>-CH<sub>3</sub> n-hexane;  
CH<sub>3</sub>-CH<sub>2</sub>- CH(CH<sub>2</sub>)-CH<sub>3</sub> i-hexane

Olefins CH<sub>3</sub>-CH<sub>2</sub>- CH<sub>2</sub>- -CH<sub>2</sub>-CH<sub>2</sub>=CH<sub>2</sub> hexene

Aromatics



Benzene

C<sub>6</sub>H<sub>6</sub>**Gasoline Nomenclature**

Different nomenclatures have been in common use in many region and countries, as follow:

Gasoline	is generic at most international name
Motor spirit	is an old name
Mogas and gas	in USA have had much recent use
Petrol	English-speaking counties
Benzin	German-speaking and other countries
Essence	French-speaking countries
Gasolina	Spanish and Portuguese- speaking countries.
Benzeen	Sudan.( Alan. G. Luca 2001)

**The History of Gasoline**

In the late 19th Century the most suitable fuels for the automobile were coal tar distillates and the lighter fractions from the distillation of crude oil. During the early 20th Century the oil companies were producing gasoline as a simple distillate from petroleum, but the automotive engines were rapidly being improved and required a more suitable fuel.

In the year 1910s, laws prohibited the storage of gasoline on residential properties, Charles F. Kettering modified an IC engine to run on kerosine. However the kerosine-fuelled engine would "knock" and crack the cylinder head and pistons. He assigned Thomas Midgley Jr. to confirm that the cause was from the kerosine dropletsaporizing on combustion as they presumed. Midgley demonstrated that the knock was caused by a rapid rise in pressure after ignition, not during preignition as believed by (G.B.Kauffman 1989). This then lead to the long search for antiknock agents, in tetra ethyl lead.

In the mid-1920s gasolines were 40 - 60 Octane, because sulfur in the gasoline inhibited the octane-enhancing effect of the alkyl lead, the sulfur content of the thermally-cracked refinery streams for gasoline was restricted. By the 1930s, the petroleum industry had determined that the larger hydrocarbon molecules (kerosene) had a major adverse effects on the octane of gasoline, and were developing consistent specifications for desired properties. In the

1940s catalytic cracking was introduced, and gasoline compositions became fairly consistent between brands during the various seasons.

The 1950s saw the start of the increase of the compression ratio, requiring higher octane fuels. Octane ratings, lead levels and vapour pressure increased, whereas sulfur content and olefins decreased. Some new refining processes (such as hydrocracking), specifically designed to provide hydrocarbons components with good lead response and the octane were introduced.

Minor improvements were made to gasoline formulations to improve yields and octane until the 1970s - when unleaded fuels were introduced to protect the exhaust catalysts that were also being introduced for environmental reasons. From 1970 until 1990 gasoline were slowly changed as lead was phased out, lead levels plummeted, octane initially decreased and then remained 2-5 numbers lower, vapour pressures continued to increase and sulfur and olefins remained constant, while aromatics increased.

In 1990, the US Clean Air Act started forcing major compositional changes on gasoline, resulting in plummeting vapour pressure and increasing oxygenate levels.

These changes will continue into the 21st Century, because gasoline use in SI engines is a major pollution source. Comprehensive descriptions of the changes to gasoline this century have been provided by (L.M.Gibbs 1993). The move to unleaded fuels continues worldwide, however several countries have increased the aromatics content (up to 50%) to replace the alkyl lead octane enhancers. These highly aromatic gasoline's can result in damage to elastomers and increased levels of toxic aromatic emissions if used without exhaust catalysts.

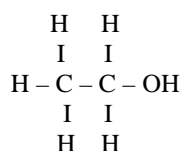
#### **What is ethanol**

Ethanol,  $\text{CH}_3\text{CH}_2\text{OH}$ , is an alcohol, a group of chemical compounds whose molecules contain a hydroxyl group,  $-\text{OH}$ , bonded to saturated a carbon atom. The classification of alcohol depends on the alkyl group to which the hydroxyl group is attached:



The common name of ethanol is ethyl alcohol, and the chemical structure of ethanol is shown below.

Ethanol



Properties of ethanol (so as to be used as fuel)

Ethanol is a known 'octane enhancer' and 'oxygenate', the octane enhancer is a component added to petrol to increase, the research octane number and to reduce engine knock. An oxygenate is a fuel octane component containing hydrogen, carbon and oxygen in its molecular structure.

Ethanol is by far the most common alcohol used in gasoline blend component as been described by (Alan. G. Lucas 2001).

O2 wt%	35
RON (research octane number)	111
RVP kPa	17
Boiling point,	$^{\circ}\text{C}$ 78

Ethanol (ethyl alcohol) is a clear, colorless liquid with a faint odor, and it has a high latent heat of vaporization Ethanol can be manufactured.

Ethanol could be used as an automotive fuel by itself and can be mixed with petrol to form an ethanol/petrol blend, the most common uses are:

10% ethanol (known as E10). 85% ethanol (known as E85); this blend is used in some states of the US and requires particular vehicle technology known as 'Flexible Fuel Technology' (FFT).

20 - 24% ethanol (known as E22); this blend, used in Brazil, requires specific vehicle optimizations (re-calibration and component changes) for 22% ethanol and 100% ethanol (E100), this is also used in Brazil and requires vehicle technology dedicated to the fuel, (Petrol Environment Australia 2002) .

#### ASTM D 4814

It is the standard specification for automotive spark ignition engine fuel, there are several test method encompassed in the ASTM D 4814 specification. It should also be noted that in addition to ASTM standard, some petroleum companies and pipeline operators may have specifications which go beyond the ASTM guidelines. For instance, some refiners may specify a higher minimum motor octane or use of specific deposit control additive, World Wide Fuel Charter, (World – Wide Fuel Charter. DEC.2002).

#### World –Wide Fuel Charter

Manufactures who own Fuel Quality Document (WWFC) are:-

1. European Automobile Manufacturers Association (ACEA),
2. Alliance of Automobile Manufacturers Association (EMA),
3. Engine Manufacturers (EMA),
4. Japan Automobile Manufacturers Association (JAMA),(World Wide Fuel Charter. DEC.2002).

#### The Sudanese standard specification of motor gasoline

Table (1) The Sudanese Standard Specification of motor gasoline

Properties	Specifications	Test Method
Density at 15 °C kg/m <sup>3</sup>	Report	ASTM D 1298
Research Octane (RON)	min. 90	ASTM D 2699
Lead content g/l	max. 0.013	ASTM D 3237
DISTILLATION		
10% recovered °C	max. 70	ASTM D 86
50% recovered °C	max. 120	
90% recovered °C	max. 190	
FBP °C	max. 205	
20% - 10% evaporated °C	min. 8.0	
Residue %V	max. 2.0	
R.V.P: Kpa		
1st Nov--31Mar.	45-----80	ASTM D 323
1stApr--31Oct.	40-----67	
Existing Gum mg/100 ml	max. 5.0	ASTM D 381
Induction Period minutes	min. 240	ASTM D 525
Sulfur Content %m	max. 0.1	ASTM D 5453
Doctor Test	negative	IP30 or ASTM D 4952
Copper Strip Corrosion Rating	max No. 1	ASTM D 130

Source: Sudanese Petroleum Corporation, General directorate of Down Stream Operation

## MATERIALS AND METHODS

#### Samples collection

In this study gasoline samples were collected from Khartoum refinery from Fluid Catalytic Cracking unit (FCC), the Reformat Gasoline unit (RFG) and finished product.

Finished product was the blended of gasoline produced from different production units like FCC and RFG, and ready for the end user.

The samples collected were:

Gasoline produced from FCC unit.

Gasoline produced from RFG unit.

Finish gasoline.

The samples prepared were:

Oxygenated samples prepared by different blend ratios of finished gasoline and ethanol, as follows

1. 5 % of Ethanol (E5).

2. 7.8 % of Ethanol (E7.8).

3. 10 % of Ethanol (E10).

Gasoline consisted almost entirely of a mixture of hydrocarbons derived from Crude oil and boiling between 25°C to 220°C (G. D. Hobson, 1984) the separation and quantization of hydrocarbon group of gasoline is difficult because it deals with a large number of very similar molecules. Therefore, the most typical method for the compositional analysis of total paraffinic, naphthenic and aromatic hydrocarbons is Gas Chromatography (D.R.P. Thichaut 1999 and Dan, C.V, Joseph C.R 2000, J. M. Andrade, S, 1995) Gas Chromatography is the most powerful and typical separation method for the compositional analysis of a complex mixture of petroleum hydrocarbon (J Newsd, M. 1997), (Min-Sik, K1, et al). The advantage of GC/FID is its sensitivity to a broad range of hydrocarbon compounds. Flame Ionization Detectors are destructive detection system because the analyte is combusted during detection (Environmental Media, 1998).

#### **Gas Chromatography (GC) ASTM D 5134**

The GC used is PIONA analyzer model Varian CP 3800 with flame ionization detector (FID) which is used to detect compounds that produce ions when burned. The flame maintained by burning air and hydrogen, the FID is ideal for analyzing hydrocarbons.

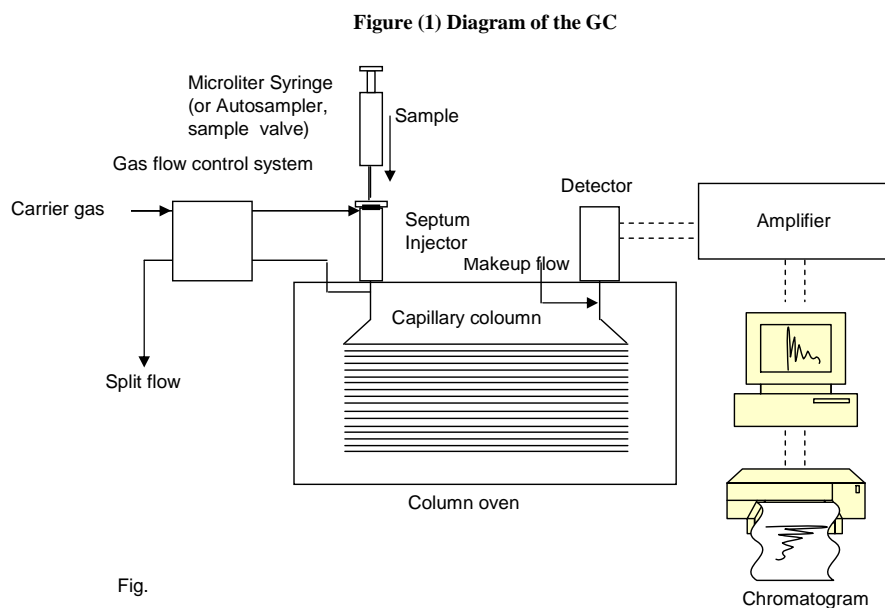
An auto sampler model CP 8410 is mounted above the oven of the GC. The column used is WCOT fused silica 100M \* 0.25mm ID, coated CP Sil PONA. The software used in this model called Star Workstation.

#### **The operating conditions**

Column temperature programming

Initial temperature	35° C
Hold time	15 min.
Program rate	1° C /min
2nd temperature	60° C
Hold time	20 min.
Program rate	2° C /min
Final temperature	200° C
Hold time	10 min.
The detector	
Temperature is set at	300° C
Fuel gas is hydrogen	(30ml/min)
Oxidizing gas is Air	(300ml/min)
The injector	
Temperature is set at	275° C
Split ratio is	200:1
Sample size is	0.2µL
Carrier gas helium He (column flow rate 5ml/min)	

Standard is a PIANO ID KIT from Alpha PIONA Calibration standards SUPELCO contain 135 components of hydrocarbon of different groups (paraffin, iso-paraffin, aromatic, naphthene, and olefin)



### Procedure

1. The operating conditions of the gas chromatograph were adjusted as it listed above.
2. The detector turned on, the flame ignited and the systems allowed to equilibrate.
3. 0.2 $\mu$ L of the PIANO ID KIT standard injected.
4. The chromatogram of the standard produced.
5. The Retention Time (RT) and Area (A) of each component peak measured.
6. The weights (W) injected were known from the certificate of the standard.
7. The ratio of A/W is calculated for each peak, this ratio known as Response Factor (RF) of the component.
8. The identification of the components based on comparison of the Retention Time (RT) of the unknown component of the sample with that obtained from the known component from the standard.
9. The weight of each component in the sample can be calculated by dividing its area by the its Response Factor (RF)

The result of the analysis of the samples shown in Table (2)

**Table (2) The hydrocarbon groups content in vol% in different type of gasoline by gas chromatography**

	Ave. Vol%					
	E5	E7.8	E10	Finish G	RFG	RFCC
Aromatics	16.09	15.35	15.32	16.82	43.77	12.90
Iso-Paraffins	31.41	30.94	31.00	36.02	34.54	33.95
Naphthenes	8.69	8.49	8.25	6.92	0.89	8.72
Olefins	27.22	26.20	23.78	28.54	3.64	34.15
Oxygenates	4.96	8.29	10.24	0.17	0.01	0.67
Paraffins	9.76	9.02	8.99	9.61	16.71	6.63
Unknowns	1.90	1.73	2.41	1.92	0.44	2.98

**Table (3) BTEX content in vol% in deferent type of gasoline by gas chromatography**

	Ave. Vol%					
	E5	E7.8	E10	Finish G	RFG	RFCC
Benzene	1.26	1.23	1.09	1.31	2.16	1.06
Toluene	3.51	3.34	3.20	3.37	11.60	1.49
Ebenzene	0.84	0.78	0.76	0.81	2.67	0.54
m-Xylene	2.96	2.75	2.73	2.85	7.35	1.92
p-Xylene	1.02	0.95	0.95	1.03	2.40	0.57
o-Xylene	1.41	1.30	1.27	1.35	4.11	0.93
Total	11.01	10.35	10.00	10.72	30.30	6.52

BTEX is Benzene, Toluene, Ebenzene, Xylene

**Ried Vapour Pressure ASTM D 323**

ASTM D 323 — test method for vapor pressure of petroleum products D 323 cannot be used to measure the vapor pressure of gasoline containing ethanol

ASTM D 4953 — test method for vapor pressure of gasoline and gasoline-oxygenate blends (dry method).

Vapour pressure of all volatile fractions is measured by the RVP apparatus at  $(38 \pm 0.1 \text{ } ^\circ\text{C})$ . The apparatus consist of two chambers. The lower chamber is in the form of cylindrical bomb for holding the test sample. Above this, there is air chamber which is a hollow cylindrical space, designed to posses four times the bomb volume. The top portion of the chamber is fitted with bourdon gauge for pressure indication.

For the test, the bomb was first filled with the sample up to the brim and immediately the valve was closed and connected to the air chamber. The apparatus was immersed in a water bath kept at  $38 \pm 0.1 \text{ } ^\circ\text{C}$ . The maximum pressure indicated by the gauge was counted as the Reid Vapour Pressure of the sample.

**Table (4) The RVP of the blending components and finished gasoline**

	RFG	FCC	FINISH	E 5	E 7.8	E 10
R.V.P@37.8°C(kPa)	54.5	58	62	64	64	64

Standard test method for research octane number of spark-ignition engine fuel ASTM D 2699

This test method employ a Cooperative Fuel Research (CFR) single-cylinder, variable-compression, knock-test engine. The engine was operated under different test conditions of speed, mixture temperature, and spark advance for each method. The compression ratio of the test engine was adjusted to produce a knock of standardized intensity for the test gasoline — the gasoline being rated. Then the primary reference fuel whose knock intensity matches that of the test gasoline at the set compression ratio was identified. The octane number of the reference fuel was the octane number of the test gasoline.

The series of primary reference fuels were blend of normal heptane (octane number defined equal to zero) and isooctane (2, 2, 4-trimethylpentane — an octane number defined equal to 100). The octane number of each primary reference fuel was equal to the volume percent of isooctane it contains.

**Table (5) The octane number of the blending components and finished gasoline**

	RFG	FCC	FINISH	E 5	E 7.8	E 10
Octane number RON	90.5	90.6	90.1	92.6	92.9	93.7

**API Gravity**

ASTM D 1298 — standard practice for density, relative density (specific gravity), or API gravity of crude petroleum and liquid petroleum products by hydrometer method.

The API gravity is measured in degrees and is calculated using the formula

$$\text{API Gravity} = (141.5/\text{SG}) - 131.5$$

FOR D 1298, the sample was placed in a cylinder and the appropriate hydrometer was lowered into the sample. After temperature equilibrium had been reached, the sample temperature and hydrometer scale reading were recorded. The Petroleum Measurement Tables were used to convert the recorded value to the value at a standard temperature such as  $60^\circ\text{F}$  or  $15^\circ\text{C}$ .

**Table (6) The density in g/cm3 of the blending components and finished gasoline**

	Finish	E5	E7.8	E10
Density g/cm3 max.	0.7212	0.7260	0.7262	0.7276

**Sulfur content ASTM D 4294** by energy dispersive X-ray fluorescence spectrometry The X-ray fluorescence spectrometry instrument (XRF), used is bench top XRF analyser model Lab-X 3500 , contain a small X-ray tube,

using helium gas supply for optimum analytical performance .The Lab-X 3500 fitted with Oxford instruments analytical software package.

The sample was placed in the beam emitted from an X-ray source. The resultant excited characteristic X radiation was measured, and the accumulated count was compared with counts from previously prepared calibration samples to obtain the sulfur concentration in mass %. Two groups of calibration standards were required to span the concentration range 0.015 to 5 mass % sulfur (0.015 to 0.1 and 0.1 to 5.0 %). The result shown in table (7)

Procedure

**Table (7) The sulfur content of the blending components and finished gasoline**

	Finish	E5	E7.8	E10
Sulphur wt %	0.0245	0.0236	0.0158	0.0146

#### **Existent gum unwashed ASTM D381 test**

Existent gum, as already available in solution, is to be separated by evaporation of the volatile gasoline. In this test first the beaker was weighted empty; a sample of 50 ml. was evaporated with the aid of a heated jet of air, while the sample was marinated at 160 – 166 OC. After the evaporation of the sample the residue was weighted. Usually gum content should not exceed 6 – 10 milligrams per 100 ml. of gasoline.

**Table (8) Existing gum of the blending components and finished gasoline**

	Finish	E5	E7.8	E10
Existing gum, mg/100ml max.	0.8	2.0	1.2	0.8

#### **ASTM distillation ASTM D 86**

In this test 100ml of sample was distilled in a standard flask at a uniform rate of 4- 5 ml per minute. The distillate was condensed, in a brass tube condenser, surrounded by a water bath kept at 0 oC by ice – water mixture. First drop from the condenser was available in 5 to 10 minutes after heating started, at which the recorded temperature was mentioned as initial boiling point (IBP) of the sample. The vapor temperature was recorded at each successive 10 cc distillate collected in a measuring cylinder. The test continues in the same way till 95% of fraction is condensed. At this juncture, the heat intensity may be increased to obtained the maximum boiling point also known as end point (EP). The result shown in Table (9).

**Table (9) Distillation of the blending components and finished gasoline**

	FINISH	E5	E7.8	E10
IBP @ Deg. C.	51	37	36	39
10% recovery Deg. C.	52	50	50	52
50% recovery Deg. C.	93	88	79	72
90% recovery Deg. C.	157	155	155	153
EBP recovery Deg. C.	180	179	178	180
Final recovery	98	97	97	99
Residue by volume	1.4	1.3	1.1	0.9

#### **Colour**

This is only for the purpose of identification between grades ,in the Sudan there is only one type of gasoline sold , ant it is not specified in the Sudanese standard specifications.

#### **Doctor test ASTM D 4952**

This test method primarily for the detection of mercaptans in gasoline. Sulphur present as mercaptans or hydrogen sulfide in distillate fuels and solvents can attack many metallic and non- metallic materials. A negative result in doctor test ensures that concentration of these compounds is insufficient to cause such problems in normal use.

In a test tube 10ml of the sample was mixed with 5 ml of sodium plumbite solution and was shaken vigorously, for 15 seconds . A small quantity of powdered sulphur was added , and was shaken again for 15 seconds. And had been settled for 2 minutes. It was observed that sample remained unchanged I n colour and the sulphur filmed was bright yellow which, indicates a NEGATIVE result regarding the presence of sulphur.



**Copper strip corrosion ASTM D 130**

Elemental sulphur, mercaptans and hydrogen sulphides which are present in petroleum fuels are corrosive to engine parts and therefore are controlled.

In this test a clean and smoothly polished copper strip was immersed in the gasoline sample, which is then maintained at temperature 50°C for 3 hours. The strip was moved from the gasoline sample, washed with acetone (solvent free of sulphur). It is then when compared with the ASTM copper strip corrosion standard found Class No. 1.

**RESULTS AND DISCUSSION**

The Sudanese gasoline blended with the ethanol of different ratios. The octane number increased noticeably from 90.1 for the finished gasoline to 93.7 when adding 10% ethanol to the finished gasoline. Also there is increase in the octane number by 92.6 and 92.9 for the addition of 5% and 7.8% ethanol to the finished gasoline respectively (Table (5)). From these additions it is concluded that the addition of 10% (E10) to the gasoline enhanced the octane number which is became approximately near the best values of the WWFC, and the British standard. Moreover the addition of 10% ethanol to the finished gasoline makes value of octane number and much better than the Indian standard specifications.

**The olefin** content decreased with the increase of the percentage of ethanol, the average of it by volume is 27.22% in E5, 26.20% in E7.8 and 23.78% in E10 (Table (2)). The benzene and aromatics contents decreased with the increase of the percentage of ethanol, which is 1.31, 16.824 for finish, 1.26, 16.09 for E5, 1.23, 15.35 for E7.8 and 1.09, 15.32 for E10 respectively. The benzene content of the gasoline blends is found over the allowable range of the WWFC, British and Emirates standard specifications, but it is much better than that of the Emirates and India standard it were much better.

**The Reid Vapor Pressure (RVP)** property of the Sudanese gasoline produced from Khartoum refinery is 62 kPa it increased by 2 kPa to 64 when measuring the RVP of the blends E5, E7.8 & E10, which is within the range of the RVP of the Sudanese standard specifications.

When comparing the wt% of the sulphur content in the current Sudanese gasoline with the blended gasoline, it is found that the increasing of ethanol percent decreased the sulphur content.

**The existing gum** level in gasoline manage by the Sudanese, the British and the WWFC Standards is maximum 5.0 mg/100ml as shown in table (3.2), while in the current Sudanese gasoline produced from Khartoum refinery was found 0.8 mg/100ml, and the gasoline blends E5, E7.8 and E10 were found 2.5, 1.2 and 0.8 respectively, which are in the range of these standards above. The gum level in the Emirate Standard is maximum 4.0 mg /100ml.

**The copper corrosion** recommended by the Sudanese, the British and the WWFC Standards is of Class 1 (3 hours at 50°C), and also the current Sudanese gasoline produced from Khartoum refinery and the gasoline blends (E5, E7.8 and E10) were found the same as recommended by the standards above Class which is 1.

**The distillation** property of gasoline based on the ambient temperature of the market. The WWFC classify each its categories in five different classes depend on the range of temperature.

The distillation of the current Sudanese gasoline produced from Khartoum refinery and the gasoline blends (E5, E7.8 and E10) are found within the range of the Sudanese standard as shown in Table (1) and WWFC category 4 class A (the ambient temperature). It was found that there a reduction of temperatures occurred in the front end of the distillation.

**Doctor test in this test** the current Sudanese gasoline produced from Khartoum refinery and the gasoline blends (E5, E7.8 and E10) were found Negative. A negative result in doctor test ensures that concentration of these compounds is insufficient to cause such problems in normal use, which are matching the Sudanese standard.

Table (10) Standard specifications

	WWFC	British	Emirates	India	Sudan
Aromatics % v/v max.	35.00	42.00	45.00	45.00	
Benzene % v/v max.	1.00	1.00	3.00	5.00	
Olefin % v/v max.	10.00	18.00	30.00	30.00	
Octane Number (min)	95.0	95.0	97.0	87.0	90.0
RVP kPa	45.00-60.00		60.00	60.00	
Density g/cm <sup>3</sup> max.	0.7800	0.7750	0.7700	0.7500	
Sulphur Content wt% max.	Sulphur free	0.015	0.1		0.1
Existing gum, mg/100ml max.	5.0	5.0	4.0		5.0
Doctor test			Negative		Negative
	Sudan	1st.Nov.-- 31Mar.	1st Apr. --31 Oct.		
	RVP ,kPa	45 --- 80	40 --- 67		

### CONCLUSION

The current Sudanese gasoline is roughly equivalent to the WWFC category 1 and much better than the Indian specifications.

From this study the octane number of the current Sudanese gasoline produced from Khartoum refinery is found low as compared with the WWFC and the British standard specifications, and is much better than that of the Indian standard specification,

The current Sudanese gasoline has a very good specification value of the aromatics content world wide specially when compared it with the British and the WWFC standard specifications. Also the current Sudanese gasoline has an intermediate value of benzene content and olefin content when compared with the British, WWFC standard, and the Emirate, the Indian standard.

The sulphur content by wt% in the current Sudanese gasoline is much better than that of the Emirate standard and slightly near the range of the British and over the allowable range the WWFC.

Other analysis like unwashed existing gum and copper corrosion of the Sudanese gasoline are within the British and the WWFC standards

The result presented in this study shows that the addition of ethanol to the gasoline obtained a greatest improvement in octane number, e.g. the use of 10% ethanol will increase the octane number to 3.6 points. Also there are noticeably decreasing in aromatics, benzene and sulphur contents, and there is a major reduction of olefins substantially with the ethanol volume, which is to somewhat a better environmental outcome will be achieved. Due to one of the major properties of gasoline the RVP, there is an increase in it by 2 kPa when blending with ethanol, which is still in the range of the Sudanese national standard, which determined to be 67 kPa.

#### Recommendations:

1. The Sudanese petroleum corporation should select suitable and compatible option with relevant international standard for Sudanese national fuel quality specially for setting limit of aromatics, olefins, and benzene content of gasoline, and to be implemented in national basis.
2. Economical studies should be useful to determine the visibility study of using oxygenated fuel (by adding one of the ratios of ethanol recommended in the study).
3. Since the FCC unit in Khartoum refinery is the major producer of gasoline, it is important to improve the quality of FCC gasoline by reducing the olefin content still with high octane number. This can be done by operational modification to FCC unit or by significant investment to the refinery configuration by adding alkylation unit (alkylate is an excellent blending component for high octane number, free of lead, benzene and olefin. It is relatively clean but expensive).
4. Since the reformat unit is the main producer of aromatics (about 43%), operational modification to reformat unit require to reduce the aromatics content. Isomerisation process also can play apart on reducing of aromatics. (Isomerate is a sulfur free, low olefin, aromatics and benzene, high octane, super clean but expensive). These solutions will be specifically depending upon the refinery configurations and governmental regulations.

**Acknowledgment**

The experimental works of this study was done in the Central Petroleum laboratories (CPL), at Ministry of energy and Mining.

We would like to express our thanks to my Dr, Hisham G.A. Lutfi for his guidance, support and comments.

We are very grateful to Dr. Mostfa M. Osman for his support. Our thanks are also extended to Dr. Awad Bab Elkhair, head section of research and development, at the Central Petroleum laboratories (CPL), for his assistance, and comments, and suggestions.

Our great thanks are also extended to our colleagues in the Central Petroleum laboratories (CPL) for their contributing and co-operation, specially Omer Babiker and Isam Yousif, , Marwa M. Adam, Amani Abd Elgader.

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