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A Comparative Study of Selected Fresh and Used Motor Oil Brands in Nigeria

*Adebimpe D. Adesina, Samuel O. Sojinu, Kehinde R. Balogun, John E. Fadumiye, Basit A. Quadri and Gafar A. Ajibowu

Department of Chemistry, Federal University of Agriculture, Abeokuta, Nigeria.

*Corresponding Author: adesinaad@funaab.edu.ng

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ABSTRACT

Motor oil is a lubricant used in internal combustion engines. This study investigated the chemical composition of fresh and used motor oil by analysing its organic contents, heavy metals and changes in physicochemical parameters. Fresh and used oil samples were collected from four motor oil brands in Nigeria: Mobil, Total, Sea Horse and Super V. The concentration of heavy metals in used oil was higher than in fresh oil. The lead content in used oil was 0.048, 0.029, 0.009 and 0.336 (mg/L) while the copper content was 0.052, 0.181, 0.096 and 0.3746 for Mobil, Total, Sea Horse and Super V respectively. The pH of the used oil samples was 7.3, 9.2, 9.5 and 7.2 while that of the fresh oil samples was 9.2, 13.3, 12.2 and 13.1 for Mobil, Total, Sea Horse and Super V oil brands respectively. The physicochemical parameters analysis showed that the density and flow rate at 40 °C of fresh oil was higher than in used oil for all oil brands except Sea Horse. Similarly, the used oils had lower viscosity when compared to fresh oils. The study concluded that fresh motor oil is denser, more viscous, has a lower pH and contained more saturated hydrocarbons than used oil samples.

Keywords: Chemical analysis, Fresh oil, Lubricant, Used oil, Viscosity

INTRODUCTION

Lubricants have been used in automobiles for a long time and play a crucial role in the smooth functioning of a vehicle. They also serve secondary purposes such as corrosion reduction, maintaining running temperatures and increasing the life of engine components [1]. Lubricants are typically oil-based, plastic, solid, or a combination of these materials, with oil or grease, being the most common type.

A lubricant (motor oil) is any material comprising base oils enhanced with additives, like anti-wear additives, detergents, dispersants and viscosity improvers for multi-grade oils to extend the life of the engine components. Motor oil is used to lubricate the internal parts of an engine, reduce friction and wear on moving parts, clean the engine from combustion residues, neutralise acids from fuel and oxidation, improve sealing of piston rings, protect

against tarnish and corrosion, and cool the engine by carrying heat away from moving parts [2-4]. Motor oil plays a key role in maintaining viscosity even at higher running temperatures. Used lubricating oil, often called waste oil, is any lubricant, whether refined from crude or synthetic components, that has been contaminated by physical or chemical impurities through use [5]. Over time, motor oil can become contaminated with metals, dirt, and other impurities, which can affect its ability to lubricate effectively. The composition of used oil differs from fresh oil due to degradation from engine use resulting in higher concentrations of contaminants and impurities.

Oil analysis is widely accepted as a form of preventive maintenance [6]. It is an important part of the maintenance strategy for various equipment and is crucial for equipment with lubricating systems. Lubricating oils undergo chemical changes due to oxidation and pollution, reducing their effectiveness [2,7].

The flashpoint, specific gravity, kinematic viscosity at 40 °C and 100 °C, viscosity index, and sulphated ash of fresh and used engine oil of Pakistani multi grade (SAE-20W/50, SAE-15W/40) and mono grade (SAE40) have been investigated and compared by Iqbal et al. [8]. Comparative investigation of heavy metals in fresh and used lubricating oils has also been reported [9-10].

This paper presents an investigation into the chemical contents of selected motor oil brands in Nigeria to identify when they become spent. The aim of this work is to determine the difference in organic content, physicochemical parameters, and heavy metal content between selected fresh and used motor oil samples in Nigeria as a comparative study.

MATERIALS AND METHODS

A common technique for evaluating the chemical composition of motor oil is gas chromatography (GC), which can be used to analyse the different components of oil and assess their relative concentrations. GC can be used to identify and quantify the different hydrocarbons and other organic compounds in the oil, as well as any additives that may be present. Other techniques that are commonly used in the analysis of motor oil include Fourier transform infrared (FTIR) spectroscopy, and atomic absorption spectroscopy (AAS), which can be used to identify and quantify the levels of different metals, such as lead, copper, and zinc with other inorganic compounds that are present in the oil. These techniques can be used to assess the quality and performance of motor oil.

Fresh and used motor oil samples were chemically analysed for volatile organic compounds and heavy metals.

Fresh oil samples were collected from four motor oil brands in Nigeria: Mobil, Total, Sea horse and Super V while the used oil samples were collected from car owners that used the corresponding fresh oil.

Extraction of Organic Contents

The extraction of the hydrocarbons was done by centrifuging the oil samples followed by column chromatography and characterisation using GC-MS to analyse the hydrocarbons in the fresh and spent oil samples. Exactly 3 mL of each oil sample was measured into the centrifuge tube and 5 mL of MeOH-DCM mixture (3:1) was added. The sample was shaken to homogenise it. The centrifuge was set at 4000 rpm for 20 min. The extract was taken out with a syringe and the solvent allowed to evaporate [11].

Chromatographic separation of the extract

Column chromatography of each extract was carried out using silica and alumina (2:1). Three fractions were eluted from the column chromatography. The saturated compounds were separated with *n*-hexane (F1), the aliphatic compounds with *n*-hexane-DCM mixture (7:3) (F2), and the polar compounds with methanol (F3). The solvent was allowed to evaporate and the oil samples were placed in sample vials which have been preheated for four hours in the oven for GC-MS analysis to determine the organic content [12].

Determination of the physicochemical parameters

Physicochemical parameters such as viscosity, flow rate and density were determined using standard procedures. Fresh and used motor oil viscosity was measured at two temperatures, 40 °C and 100 °C using a capillary viscometer (Brookfield DV2T extra). The sample was allowed 10 min to come to bath temperature at 40 °C and 15 min at 100 °C. The density and flow rate of the oil samples were also determined.

Heavy metal determination

Heavy metal analysis of the oil samples was done using the Atomic Absorption Spectrometer. Exactly 2 mL of each oil sample was measured into a flask and a mixture of HNO_3 and HCl (4:1) was added. The mixture was heated until all the fumes were completely evaporated. The mixture was then cooled to room temperature, made up to 50 mL with deionized water, and filtered. The filtrate was stored in clean polyethylene storage bottles for AAS analysis [10,13].

RESULTS AND DISCUSSION

Distribution of organic compounds in the oil samples

The results of the GC-MS analysis of the saturated fractions (F1) from the column chromatography of the fresh and used oil samples of Mobil Oil brand are shown in Table 1.

Table 1: GC-MS results of the saturated fractions from fresh and used oil samples of Mobil Oil fraction 1

	Mobil Fresh Oil (MFF1)			Mobil Used Oil (MUF1)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.55	Toluene	5.09	2.78	1-Octene	1.79
2	2.79	1-Octene	2.54	3.16	2,4-Hexadiene, 2,3-dimethyl-	1.73
3	3.15	Cyclohexene, 1,2-dimethyl-	2.29	3.45	1-Heptene, 2,6-dimethyl-	1.43
4	3.96	1-Nonene	3.34	3.96	Cyclopropane, 1-methyl-2-pentyl-	4.01
5	5.26	1-Decene	3.08	5.26	1-Decene	2.75
6	6.56	Cyclopropane, 1-methyl-2-pentyl-	2.80	5.97	Indene	1.64
7	7.80	1-Dodecene	2.91	6.56	1-Decanol	2.66
8	8.98	1-Tridecene	2.09	7.40	Cycloprop[a]indene, 1,1a,6,6a-tetrahydro-	1.70
9	10.09	4-Tetradecene, (E)-	2.09	7.80	1-Dodecene	2.72
10	11.14	1-Pentadecene	2.24	8.98	1-Tridecene	2.29
11	12.13	1-Nonadecene	2.51	10.09	2-Tetradecene, (E)-	2.07
12	12.21	Hexadecane	1.93	10.18	Tetradecane	2.41
13	13.14	Heptadecane	2.15	10.70	Cyclotetradecane	1.19
14	13.25	Heptacosane	3.25	10.79	Dodecane, 4-methyl-	1.46
15	13.64	Tetrapentacontane, 1,54-dibromo-	1.55	10.84	Decane, 2-methyl-	1.54
16	13.97	n-Nonadecanol-1	1.86	10.92	Decane, 3,8-	1.14

					dimethyl-	
17	14.03	Octadecane	3.54	11.15	1-Pentadecene	2.14
18	14.11	Hexadecane, 2,6,10,14-tetramethyl-	2.01	11.23	Pentadecane	3.56
19	14.88	Hexadecane	3.08	12.14	Heptafluorobutyric acid, n-tetradecyl ester	2.06
20	15.10	Octadecane	3.18	12.23	Hexadecane	5.56
21	15.69	Eicosane	3.89	12.68	2-Bromo dodecane	3.51
22	16.28	Octatriacontyl pentafluoropropionate	2.96	12.76	Ethanol, 2-(tetradecyloxy)-	1.85
23	16.36	9-Tricosene, (Z)-	3.40	12.81	Hexadecane, 2-methyl-	1.22
24	16.47	Heneicosane	2.73	13.09	1-Heptadecene	1.17
25	16.72	Octatriacontyl trifluoroacetate	1.85	13.18	Heptadecane	5.48
26	16.77	Eicosane	3.80	13.23	Pentadecane, 2,6,10,14-tetramethyl-	5.08
27	17.02	Octatriacontyl pentafluoropropionate	2.09	14.14	Hexadecane, 2,6,10,14-tetramethyl-	3.30
28	17.07	Dotriacontyl heptafluorobutyrate	2.81	14.84	1-Nonadecene	1.72
29	17.22	Octadecane	2.44	14.92	Octadecane	4.79
30	17.49	Nonadecane, 1-chloro-	8.86	15.73	Eicosane	4.41
31	17.81	Cyclotetradecane, 1,7,11-trimethyl-4-(1-methylethyl)-	1.95	16.50	Heneicosane	4.02
33	17.93	Tetratriacontyl heptafluorobutyrate	1.68	17.08	1-Nonadecene	1.18
34	18.19	Tetrapentacontane, 1,54-dibromo-	2.81	17.24	Docosane	3.08
35	18.87	Hexatriacontyl pentafluoropropion	3.19	23.99	Baccharane	2.02

	ate				
36			25.08	16-Deoxokryptogenin	1.13

Toluene, 1-Nonene, and 4-Tetradecene, (E)- were present in MFF1 sample as shown in Table 1 but absent in MUF1 sample. The disappearance of those compounds in the fresh oil sample and appearance of new compounds in the used oil sample is as a result of degradation of bigger compounds to smaller ones as a result of increase in the temperature of the oil when engine was working.

The results of the GC-MS analysis of the aliphatic compounds (F2) from the column chromatography of the fresh and used oil samples of Mobil Oil brand are shown in Table 2.

Table 2: GC-MS results of the aliphatic compounds from fresh and used oil samples of Mobil Oil fraction two

	Mobil Fresh Oil (MFF2)			Mobil Used Oil (MUF2)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.46	2-Butene, 1,4-dichloro-, (E)-	18.86	2.46	2-Butene, 1,4-dichloro-, (E)-	18.69
2	4.22	Ethane, 1,1,2,2-tetrachloro-	12.29	4.21	Ethane, 1,1,2,2-tetrachloro-	15.11
3	4.30	3-Methylpentan-3-yl 2-methylbutanoate	14.68	4.30	Hexane, 1,1'-oxybis-	17.84
4	4.85	Heptane, 1-chloro-	7.73	4.85	Heptane, 1-chloro-	7.10
5	14.95	Hexadecanenitrile	4.34	13.25	Eicosane	1.61
6	16.36	Oleanitrile	32.19	15.00	Hexadecanenitrile	3.26
7	18.64	Tert-octyldiphenylamine	3.56	15.10	Tetratetracontane	4.92
8				16.40	Oleanitrile	19.60

From this table, 3-Methylpentan-3-yl 2-methylbutanoate and Tert-Octyldiphenylamine were present in MFF2 sample but absent in MUF2 sample. The disappearance of those compounds in the fresh oil sample and appearance of new compounds in the used oil sample is due to heat which led to the breakdown of bigger compounds to smaller compounds.

The results of the GC-MS analysis of the polar compounds (F3) from the column chromatography of the fresh and used oil samples of Mobil Oil brand are shown in Table 3.

Table 3: GC-MS results of the polar compounds from fresh and used oil samples of Mobil Oil fraction three

	Mobil Fresh Oil (MFF3)			Mobil Used Oil (MUF3)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.12	Silane, trimethoxymethyl-	4.22	2.12	Silane, trimethoxymethyl-	3.18
2	2.22	Silane, trimethoxymethyl-	15.72	2.21	Silane, trimethoxymethyl-	14.84
3	2.54	Toluene	2.18	2.54	Toluene	1.01
4	2.67	Tetramethyl silicate	73.26	2.68	Tetramethyl silicate	53.12
5	3.05	Cyclotrisiloxane, hexamethyl-	1.76	2.72	Tetramethyl silicate	23.60
6	5.34	Benzoic acid, 5-methyl-2-trimethylsilyloxy-, trimethylsilyl ester	2.85	3.05	Cyclotrisiloxane, hexamethyl-	1.33
7				3.19	Cyclotrisiloxane, hexamethyl-	0.86
8				5.34	Cyclotetrasiloxane, octamethyl-	2.06

From Table 3, 5-methyl-2-trimethylsilyloxy-, trimethylsilyl ester was found to be present in MFF3 sample but absent in MUF3 sample. The disappearance of this compound in the fresh oil sample and appearance of new compound named Cyclotetrasiloxane, octamethyl- in the used oil sample is as a result of heat which leads to break down of bigger compound to smaller one.

The results of the GC-MS analysis of the saturated fractions (F1) from the column chromatography of the fresh and used oil samples of Total Oil brand are shown in Table 4.

Table 4: GC-MS results of the saturated fractions from fresh and used oil samples of Total Oil fraction 1

	Total Fresh Oil (TFF1)			Total Used Oil (TUF1)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	3.97	1-Nonene	2.57	2.33	1,4-Hexadiene, 4-methyl-	1.80
2	5.26	1-Decene	2.34	2.61	Toluene	1.73
3	6.56	1-Undecene	1.98	2.79	1-Octene	1.43
4	7.81	1-Dodecene	1.99	3.16	Cyclohexene, 1,2-dimethyl-	4.01
5	12.13	5-Octadecene,(E)-	1.89	3.45	1-Heptene, 2,6-dimethyl-	2.75
6	12.21	Hexadecane	2.42	3.96	1-Nonene	1.64
7	12.67	Methoxy acetic acid, 2-tetradecyl ester	1.77	4.79	Cyclopropane, 1-ethyl-2-pentyl-	2.66
8	13.14	Heptadecane	3.85	5.26	1-Decene	1.70
9	13.20	Tridecane, 5-propyl-	3.70	5.96	Indene	2.72
10	13.25	Hexadecane	1.82	6.50	Benzene, 1-ethenyl-3-ethyl-	2.29
11	14.04	Octadecane	5.54	6.56	5-Undecene	2.07
12	14.12	Hexadecane, 2,6,10,14-tetramethyl	7.13	7.73	Cyclopropane, 1-hexyl-2-methyl-	2.41
13	14.83	1-Hexadecanol,2-methyl-	2.13	7.81	1-Dodecene	1.19
14	14.88	Hexadecane	4.89	8.99	1-Tridecene	1.46
15	15.70	Eicosane	6.03	9.03	7-Tetradecene, (Z)-	1.54
16	16.29	Ethanol, 2-octadecyloxy-	2.31	10.10	2-Tetradecene, (E)-	1.14
17	16.47	Heneicosane	2.91	10.18	Cyclononane, 1,1,4,4,7,7-hexamethyl-	2.14
18	16.72	1-Nonadecene	1.79	11.15	1-Pentadecene	3.56
19	16.77	Octadecane, 1-	1.90	11.23	Pentadecane	2.06

		chloro-				
20	17.01	Dotriacontylpentafluoropropionate	1.98	12.14	3-Hexadecene, (Z)-	5.56
21	17.07	Dotriacontylpentafluoropropionate	3.10	12.22	Hexadecane	3.51
22	17.22	Nonadecane-1-chloro-	2.48	12.68	Pentadecane, 2,6,10-trimethyl-	1.85
23	17.48	Nonahexacontanoic acid	6.03	12.76	Ethanol, 2-(tetradecyloxy)-	1.22
24	21.33	D-Homoandrostane,(5.alpha, 13.alpha)-	3.04	13.09	1-Heptadecene	1.17
25	23.13	28-Nor-17.alpha.(H)-hopane	10.17	13.17	Heptadecane	5.48
26	23.93	.beta.-iso-Methyl ionone	5.04	13.22	Heptadecane, 2,6-dimethyl-	5.08
27	25.03	(1R,2S,8R,8Ar)-8-acetoxy-1-(2-hydroxyethyl)-1,2,5,5-tetramethyl-trans-decalin	3.84	13.99	n-Nonadecanol-1	5.26
28				14.07	Octadecane	
29				14.14	Hexadecane, 2,6,10,14-tetramethyl-	
30				14.85	1-Nonadecene	
31				14.92	Heptadecane	
32				15.73	Eicosane	
33				16.51	Heneicosane	
34				17.26	Docosane	
35				17.98	Tetracosane	
36				24.06	Baccharane	

The results of the GC-MS analysis of the aliphatic compounds (F2) from the column chromatography of the fresh and used oil samples of Total Oil brand are shown in Table 5.

Table 5: GC-MS results of the aliphatic compounds from fresh and used oil samples of Total Oil fraction two

	Total Fresh Oil (TFF2)			Total Used Oil (TUF2)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.46	2-Butene, 1,4-dichloro-, (E)-	18.74	2.46	2-Butene, 1,4-dichloro-, (E)-	18.69
2	4.22	Ethane, 1,1,2,2-tetrachloro-	34.86	2.94	2,2'-Dipiperidine	15.11
3	4.30	4-Methyl-6-(tetrahydropyran-2-yloxy)hex-4-enal	21.87	4.21	Ethane, 1,1,2,2-tetrachloro-	17.84
4	4.85	Heptane, 1-chloro-	7.12	4.30	Hexane, 1,1'-oxybis-	7.10
5	16.42	Oleanitrile	4.72	4.85	Heptane, 1-chloro-	1.61
6				13.41	1H-Indene, 2,3-dihydro-1,1,3-trimethyl-3-phenyl-	3.26

The results of the GC-MS analysis of the polar compounds (F3) from the column chromatography of the fresh and used oil samples of Total Oil brand are shown in Table 6.

Table 6: GC-MS results of the aliphatic compounds from fresh and used oil samples of Total Oil fraction three

	Total Fresh Oil (TFF3)			Total Used Oil (TUF3)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.71	Silane, trimethoxymethyl-	9.63	2.12	Silane, trimethoxymethyl-	2.97
2	2.68	Tetramethyl	89.42	2.22	Silane,	11.66

		silicate			trimethoxymethyl-	
3	5.34	Cyclotetrasiloxane, octamethyl-	0.94	2.67	Tetramethyl silicate	49.53
4				2.73	Tetramethyl silicate	33.47
5				3.05	Cyclotrisiloxane, hexamethyl-	0.54
6				5.34	Cyclotetrasiloxane, octamethyl-	1.15
7				7.35	Cyclopentasiloxane, decamethyl-	0.69

The results of the GC-MS analysis of the saturated fractions (F1) from the column chromatography of the fresh and used oil samples of Sea Horse Oil brand are shown in Table 7.

Table 7: GC-MS results of the saturated fractions from fresh and used oil samples of Sea Horse Oil fraction 1

	Sea Horse Fresh Oil (SHFF1)			Sea Horse Used Oil (SHUF1)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.61	Toluene	3.75	2.62	Toluene	3.84
2	2.79	1-Octene	2.55	2.79	1-Octene	2.44
3	3.97	1-Nonene	4.14	2.90	3-Octene, (Z)-	1.72
4	5.26	1-Decene	3.05	3.16	Cyclohexene, 1,2-dimethyl-	2.98
5	6.57	Cyclopropane, 1-heptyl-2-methyl-	3.21	3.45	1-Heptene, 2,6-dimethyl-	2.48
6	7.81	1-Dodecene	3.25	3.97	1-Nonene	5.66
7	8.98	1-Tridecene	2.43	4.79	Cyclopropane, 1-ethyl-2-pentyl-	2.29
8	10.09	3-Tetradecene, (Z)-	2.43	5.26	1-Decene	3.74
9	12.14	2-Tetradecene, (E)-	2.60	5.30	Benzene, 1,2,3-trimethyl-	4.70
10	12.21	Hexadecane	2.75	5.68	Benzene, 1-ethyl-2-methyl-	1.86

11	13.15	Heptadecane	3.25	6.56	5-Undecene	3.84
12	13.20	Hexadecane, 2,6,11,15-tetramethyl-	2.72	7.81	1-Dodecene	3.55
13	14.04	Octadecane	3.79	8.98	1-Tridecene	2.99
14	14.12	Hexadecane, 2,6,10,14-tetramethyl-	3.91	10.09	1-Tetradecene	2.44
15	14.89	Hexadecane	3.80	10.18	Cyclononane, 1,1,4,4,7,7-hexamethyl-	2.16
16	15.70	Eicosane	4.30	11.08	Cyclohexanone, 2,2-dimethyl-5-(3-methyloxiranyl)-, [2.alpha.(R*),3.alpha.]-(.+-.)-	2.18
17	16.48	Heneicosane	3.53	11.15	1-Pentadecene	2.64
18	17.23	Heptadecane	3.01	11.22	Pentadecane	1.72
19	17.50	Heneicosane	4.79	12.15	Behenic alcohol	1.78
20	23.17	28-Nor-17.beta.(H)-hopane	15.23	12.22	Hexadecane	2.86
21	23.97	28-Nor-17.alpha.(H)-hopane	7.43	12.69	Pentadecane, 2,6,10-trimethyl-	2.15
22	25.08	2,4,5,5,8a-Pentamethyl-6,7,8,8a-tetrahydro-5H-chromene	6.02	13.18	Heptadecane	2.07
23	25.23	Anthracene, 9-butyltetradecahydro-	4.92	13.23	Pentadecane, 2,6,10,14-tetramethyl-	3.54
24	26.12	Anthracene, 9-butyltetradecahydro-	3.15	14.16	Hexadecane, 2,6,10,14-tetramethyl-	2.84
25				23.21	28-Nor-17.beta.(H)-hopane	10.70
26				24.01	Baccharane	5.46
27				25.13	Baccharane	5.47
28				25.27	Baccharane	3.98

29			26.15	Baccharane	3.70
30			27.61	2-(4a,8-Dimethyl-6-oxo-1,2,3,4,4a,5,6,8a-octahydro-naphthalen-2-yl)-propionaldehyde	2.21

The results of the GC-MS analysis of the aliphatic fractions (F2) from the column chromatography of the fresh and used oil samples of Sea Horse Oil brand are shown in Table 8.

Table 8: GC-MS results of the aliphatic compounds from fresh and used oil samples of Sea Horse Oil fraction two

	Sea Horse Fresh Oil (SHFF2)			Sea Horse Used Oil (SHUF2)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.46	2-Butene, 1,4-dichloro-, (E)-	22.80	2.46	2-Butene, 1,4-dichloro-, (E)-	21.21
2	3.29	Acetic acid, dichloro-	5.52	3.29	Methylene chloride	5.87
3	4.03	Propanedinitrile, cyclopentylidene-	3.43	4.03	Ethyl 3-(3-pyridyl)propenoate	7.53
4	4.22	Ethane, 1,1,2,2-tetrachloro-	39.80	4.21	Ethane, 1,1,2,2-tetrachloro-	37.93
5	4.31	Sulfurous acid, isohexyl hexyl ester	20.65	4.31	Sulfurous acid, isohexyl hexyl ester	19.54
6	4.85	Heptane, 1-chloro-	7.80	4.85	Heptane, 1-chloro-	7.92

The results of the GC-MS analysis of the polar compounds (F3) from the column chromatography of the fresh and used oil samples of Sea Horse Oil brand are shown in Table 9.

Table 9: GC-MS results of the aliphatic compounds from fresh and used oil samples of Sea Horse Oil fraction three

	Total Fresh Oil (SHFF3)			Total Used Oil (SHUF3)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.54	Toluene	0.73	2.12	Silane, trimethoxymethyl-	3.42
2	2.67	Tetramethyl silicate	66.42	2.21	Silane, trimethoxymethyl-	10.86
3	2.72	Tetramethyl silicate	31.98	2.54	Toluene	1.39
4	5.34	Cyclotetrasiloxane, octamethyl-	0.88	2.68	Tetramethyl silicate	81.80
5				5.34	Cyclotetrasiloxane, octamethyl-	1.69
6				7.35	Cyclopentasiloxane, decamethyl-	0.84

The results of the GC-MS analysis of the saturated compounds (F1) from the column chromatography of the fresh and used oil samples of Super V Oil brand are shown in Table 10.

Table 10: GC-MS results of the saturated fractions from fresh and used oil samples of Super V Oil fraction 1

	Super V Fresh Oil (SVFF1)			Super V Used Oil (SVUF1)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	8.98	1-Tridecene	3.13	2.79	1-Octene	2.21
2	15.70	Eicosane	3.01	3.16	Cyclohexene-1,2-dimethyl	1.94
3	14.04	Octadecane	2.57	3.96	1-Nonene	3.77
4	5.26	1-Decene	4.07	4.79	Cyclopropane-1-ethyl-2-pentyl	1.12
5	10.09	2-Tetradecene(E)	2.94	5.26	1-Decene	3.97
6	16.48	Heneicosane	2.54	5.56	Ethanone,1-(2,2-dimethyl cyclopentyl)-	1.02
7	14.88	Hexadecane	2.52	6.56	5-Undecene	2.97
8	12.13	Trifluoroacetic acid,	2.67	7.80	1-Dodecene	2.93

		n-tridecyl ester				
9	6.55	Cyclopropane, 1-methyl-2-pentyl	4.16	8.98	1-Tridecene	2.30
10	3.16	Cyclohexene,1-2-dimethyl	3.19	10.09	2-Tetradecene(E)	2.17
11	16.36	9-Tricosene, (z)-	3.03	10.17	1-Octanol,2-butyl	0.94
12	2.79	1-Octene	3.22	10.77	1-Decanol,2-hexyl	1.06
13	3.45	1-Heptene, 2,6-dimethyl	2.25	11.07	Cycloundecane-1,1,2-trimethyl-	1.14
14	17.23	Tridecane	2.68	11.14	2-Tetradecene(E)	2.36
15	23.18	28-Nor-17.alpha.(H)-hopane	9.29	11.22	Pentadecane	1.34
16	23.99	28-Nor-17.beta.(H)-hopane	9.29	11.63	Dodecane	0.95
17	25.10	Anthracene,9-cyclohexyl tetradecahydro	8.44	12.14	Cyclohexadecane	2.42
18	25.26	Baccharane	5.99	12.21	Hexadecane	2.80
19	26.24	Urs-20-en-16-ol,(16beta.,18.alpha.,19.alpha)-	5.12	12.67	2-Bromododecane	1.44
20	3.96	1-Nonene	5.25	13.08	1-Heptadecane	2.13
21	7.80	1-Dodecene	3.89	13.15	Heptadecane	3.47
22	11.14	1-Pentadecene	2.86	13.20	Dodecane-2,6,11-trimethyl	2.96
23				13.25	Pentacosane	1.51
24				13.42	1-Nonadecene	0.92
25				13.64	Oxirane,tridecyl	1.23
26				13.98	1-Octadecane	2.03
27				14.04	Octadecane	3.44
28				14.13	Hexadecane-2,6,10,14-tetramethyl	1.90
29				14.84	1-Nonadecene	2.17
30				14.89	Nonadecene	4.18
31				15.11	Octadecane	1.44
32				15.66	10-Heneicosene(c,t)	1.38
33				15.71	Eicosane	3.37
34				16.37	9-Tricosene(Z)	2.63
35				16.49	Eicosane	3.02
36				17.23	Octadecane	2.06
37				17.95	Heneicosane	1.33
38				23.17	Urs-20-en-16-ol,(16.beta.,18.alpha.,19.alpha)-	5.48
39				23.98	.beta.-iso-Methyl ionone	3.45
40				25.08	Baccharane	2.69

The results of the GC-MS analysis of the aliphatic compounds (F2) from the column chromatography of the fresh and used oil samples of Super V Oil brand are shown in Table 11.

Table 11: GC-MS results of the saturated fractions from fresh and used oil samples of Super V Oil fraction 2

	Total Fresh Oil (SVFF2)			Total Used Oil (SVUF2)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	16.41	Oleanitrile	8.58	16.43	Oleanitrile	10.74
2	4.22	Ethane,1,1,2,2-tetrachloro	34.16	4.22	Ethane-1,1,2,2-tetrachloro	35.20

3	2.46	2-Butene-1,4-dichloro(E)	20.51	4.85	Heptane,1-chloro	7.40
4	4.30	Sulphorous acid, isohexyl hexyl ester	16.82	2.46	2-Butene, 1,4-dichloro(E)	18.70
5	4.84	Hexane-1-chloro	7.19	4.31	4-methyl-6-(tetrahydropyran-2-yloxy) hex-4-enal	21.32

The results of the GC-MS analysis of the polar compounds (F3) from the column chromatography of the fresh and used oil samples of Super V Oil brand are shown in Table 12.

Table 12: GC-MS results of the saturated fractions from fresh and used oil samples of Super V Oil fraction 3

	Total Fresh Oil (SVFF3)			Total Used Oil (SVUF3)		
Peak	Retention Time RT (min)	Identified Compound	Percentage Composition	Retention Time (min)	Identified Compound	Percentage Composition
1	2.12	Silane, trimethoxymethyl	2.85	2.21	Silane,trimethoxymethyl	3.47
2	2.22	Silane, trimethoxymethyl	9.88	2.22	Silane, trimethoxymethyl	12.65
3	2.68	Tetramethyl silicate	87.28	2.67	Tetramethylsilicate	82.74
4				5.34	Cyclotetrasiloxane, octamethyl	1.15

The results showed that compounds such as Hexadecane, Tridecane present in fresh oil were absent in the used oil and compounds like Baccharane, Propanedinitrile, and Decamethyl were present in the used oil but absent in the fresh oil. The disappearance of those compounds in the fresh oil sample and appearance of new compounds in the used oil sample is as a result of degradation of bigger compounds to smaller ones as a result of increase in the temperature of the oil when engine was working.

It is expected that alkanes would be present in the fresh oil brands since alkanes with 17 to 35 carbon atoms form the major components of lubricating oil. The alkanes present also act as anti-corrosive agents, as their hydrophobic nature protects the metal surface from contact with water.

The compounds present in the used oil brands are the polycyclic aromatic hydrocarbons (PAH) which are as a result of exhaustion of additives, concentrating of impurities and imperfect fuel combustion. PAH are very dangerous to health because some are known to be mutagenic and carcinogenic. The PAH content of used motor oil from petrol motors can be 180 times higher than that of new oil.

Heavy Metals in the Engine Oil brands

Table 13 shows the increase in the mass of heavy metals present in the four engine oil brands from fresh to the used engine oils as a result of wear and tear caused by friction and burning of fuel.

Table 13: Heavy metals analysis of the four motor oil brands

S/N	ELEMENT	Mobil Fresh (mg/L)	Mobil Used (mg/L)	Total Fresh (mg/L)	Total Used (mg/L)	Sea Horse Fresh (mg/L)	Sea Horse Used (mg/L)	Super V Fresh (mg/L)	Super V Used (mg/L)
1	Copper (Cu)	0.036	0.052	0.097	0.181	0.027	0.096	0.043	0.375
2	Manganese (Mn)	0.082	1.020	0.076	4.773	0.076	0.081	0.085	3.709
3	Lead (Pb)	0.062	0.048	0.020	0.029	0.040	0.009	0.014	0.336
4	Iron (Fe)	0.153	0.513	0.495	1.161	0.144	0.267	0.353	1.500

The concentration of heavy metals in used oil were found to be higher than that of fresh. The lead contents in the used oil were 0.048, 0.029, 0.009 and 0.336 (mg/L) while the copper contents were 0.052, 0.181, 0.096 and 0.3746 for Mobil, Total, Sea Horse and Super V respectively. Super V used oil was found to have the highest lead and copper content. These metals are highly toxic to organisms [10].

Another approach to evaluating spent oil is to measure its viscosity, or its resistance to flow. As motor oil is used in an engine, it can become thinner or more viscous depending on the conditions it is exposed to. For instance, high temperatures can cause motor oil to thin out, reducing its ability to lubricate effectively. Measuring the viscosity of spent motor oil can

therefore be an effective way to assess its quality and performance, and to determine whether it needs to be replaced.

The physicochemical parameters of the fresh and used oil samples from the four motor oil brands are shown in Table 14.

Table 14: Physicochemical parameters of the four motor oil brands

Oil brand	Viscosity (cP) at 40 °C		Viscosity (cP) at 100 °C		Flow rate (m3/s) at 40 °C		Flow rate (m3/s) at 100 °C		pH		Density (g/mL)	
	Fresh Oil	Used Oil	Fresh Oil	Used Oil	Fresh Oil (× 10-5)	Used Oil (× 10-5)	Fresh Oil (× 10-5)	Used Oil (× 10-5)	Fresh Oil	Used Oil	Fresh Oil	Used Oil
Mobil	255	160	115	120	80	170	1330	640	9.2	7.3	0.76	0.75
Total	290	460	245	190	21.5	460	1.5	1.2	13.3	9.2	0.78	0.75
Sea Horse	320	270	230	185	0.076	0.071	1.19	0.722	12.2	9.5	0.73	0.75
Super V	275	190	320	180	0.081	0.095	0.746	0.727	13.1	7.2	0.745	0.739

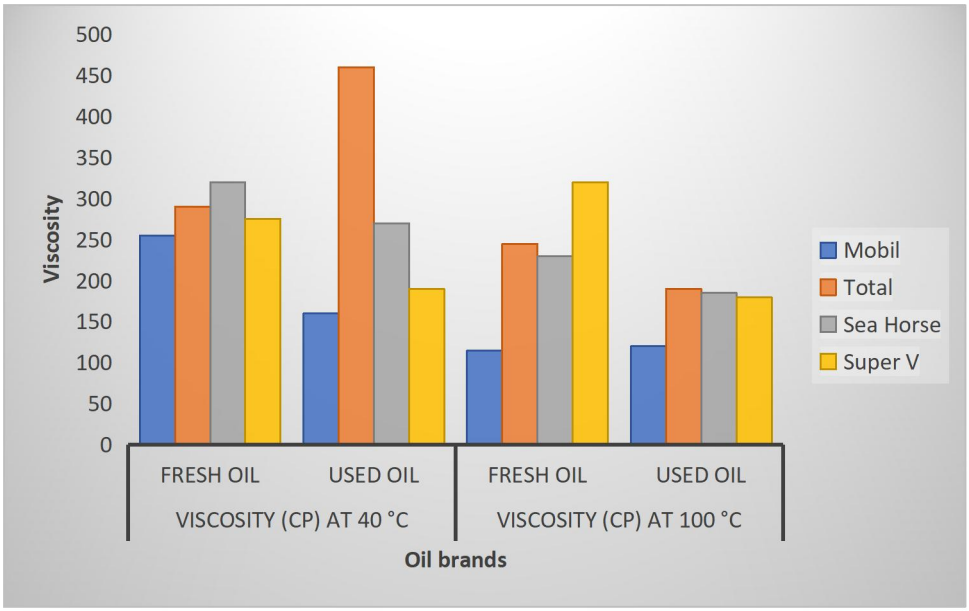

Figure 1: The variation of Viscosity with temperature increase

With high temperatures, viscosity decreases in liquids. The increase in temperature reduces the cohesive forces between the molecules of liquid and hence, the viscosity decreases.

From Fig. 1, the viscosity of used oil decreased when compared to the fresh oil at 40 °C for all the brands except Total and increased at 100 °C for all the brands except Mobil. The viscosity of fresh oil decreased with increase in temperature (from 40 to 100 °C) for all the oil brands except Super V while the viscosity of used oil decreased with increase in temperature for all the oil brands as expected [14].

CONCLUSION

The chemical components of four oil brands in Nigeria have been analysed successfully. New compounds were found in the used oil samples indicating the presence of polycyclic aromatic hydrocarbons. Of all the brands, Super V had the highest heavy metal content and an increase in viscosity with temperature rise. The study established that fresh motor oil is denser, more viscous, has a lower pH and contains more saturated hydrocarbons than used oil samples.

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