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QUALITY EVALUATION OF SELECTED PETROLEUM PRODUCTS AT SELECTED POINTS OF SALE (POS) IN MAKURDI METROPOLIS

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ABSTRACT

The levels of adulteration in petroleum product fractions of premium motor spirit (PMS), dual purpose kerosene (DPK), automotive gas oil (AGO) and lube oil were investigated. Samples were randomly collected from ten (10) points of sale (POS) i.e. filling stations within Makurdi metropolis. They were analysed for density at 15 °C, specific gravity at 15.5 °C, API gravity, dynamic viscosity, kinematic viscosity, flash point, cloud point, and pour point, using standard procedures of the American Society for Testing and Materials (ASTM). The results were compared with limits set by the Department of Petroleum Resources (DPR) in Nigeria. Results of the analyses show that most PMS, DPK, AGO and Lube Oil values slightly deviated from the DPR limits. The investigated indices of the petroleum products had ranges as respectively shown. Densities (0.71 – 0.74, 0.778 – 0.794, 0.813 – 0.858 and 0.852 – 0.885) g mL-1; specific gravities (0.72 – 0.75, 0.782 – 0.805, 0.824 – 0.867 and 0.831 – 0.891); API gravity (56.39 – 65.93, 46.15 – 49.53, 32.63 – 40.32 and 27.23 – 38.76); dynamic viscosity (0.60 – 0.70, 0.89 – 1.10, 2.66 – 3.00, and 45.50 – 48.00) cP; kinematic viscosity (0.39 – 0.97, 1.13 – 1.40, 3.16 – 3.66 and 52.80 – 54.99) cSt; flash point (27.0 – 29.0, 49.00 – 52.00, 89.80 – 91.00 and 223.30 – 224.90) ℃; cloud point (-20.30 – -19.83, -10.20 – -9.86, -6.9 – -4.6 and 6.80 – 8.16) ℃; pour point (-24.06 – -23.90, -32.03 – -20.00, -12.46 – -9.20 and 1.63 – 3.10) ℃. The results of this research reveal that the purity of virtually all the products may have been compromised or altered while in storage, during transport, by dirt invasion as well as moisture attack and may pose problems when sold to end users. It is therefore recommended that regulatory agencies should be more proactive to curb the growing menace by ascertaining the extent of purity, not only at the depots where they are received upon importation, but even more at the points of sale (POS) from where they go to the consumers.

Introduction

Products from the oil industry are very important, especially in modern society because of their versatility and position in the energy scene (Speight, 2014). In Nigeria, however, virtually all ramifications of trade and technology need petroleum fractions of a certain kind for normal running. Automobile gas oil (AGO) is used in powering auto-power generators, dual purpose kerosene (DPK) is used for domestic homesteads and premium motor spirit (PMS) is used for heating and in combustion engines of vehicles (Faruq *et al.,* 2012; Onojake *et al.,* 2012). This high demand placed on these petroleum fractions is because of the undersupply of electricity in the country as well as the country's inability to refine enough quantities of the products to meet the consumers' needs. This has created room for the adulteration of petroleum products.

Adulteration of petroleum products is an act perpetrated daily by unscrupulous people in the developing countries like Nigeria with the sole aim of maximizing profit in their business with total disregard to the hazardous effects their actions could have on end users. It is the deliberate mixing of petroleum products with a product of 'lower grade', partially refined products or condensates with products that are in high demand like PMS, DPK, AGO and even lube oil, with the intention of making more profit. Condensates (reservoir gases that condense to liquid hydrocarbons when produced) which are the major components used for the adulteration of these products are in abundant supply in countries like Nigeria. According to the Nigerian National Petroleum Corporation (NNPC, 2008), fuel adulteration is the illegal or unauthorized introduction of foreign substances into fuel, resulting in the product not meeting product requirements and specifications. The adverse effects of these adulterants are unbearable as they are usually the cause of knocking of vehicular engines and machines, increased tailpipe emissions of hydrocarbons, carbon monoxide, nitrogen oxides, particulate matter and the consequent ill effects on public health (Faruq *et al.,* 2012; Onojake *et al.,* 2012).

There are standardization systems that are designed to provide fuels with specific, fixed and comparable properties, even for products produced over different periods and supplied by different manufacturers. The properties include: API gravity, specific gravity, viscosity (cP), density at 15 °C in g cm^{-3}, cloud point (℃), pour point (℃), flash point (℃), etc. (Otobrise, 2013). Any deviation from these parameters signifies the alteration of the quality of petroleum fractions. This research therefore seeks to investigate the quality of some petroleum products sold within Makurdi metropolis and their level of conformity to or deviation from the original product specification likely due to adulteration and hence recommend ways to curb the menace.

MATERIALS AND METHODS

Samples collection:

Ten samples each of PMS, DPK, AGO and lube oil were procured at the point of sale (POS) from different locations in Makurdi metropolis. The samples were preserved in clean, airtight plastic containers prior to analysis.

Analysis:

The density at 15 ^{o}C, specific gravity at 15.5 ^{o}C and API gravity were determined using ASTM D1298-85 method (Hydrometer Method). Kinematic viscosity at 40 ^{o}C was determined using ASTM D445-06 method (Brookfield viscometer, DV – II+ Pro). Cloud point was determined by the ASTM D2500-05 method; pour point was carried out by the ASTM D97-06 method; flash point was determined by the ASTM D93-06 method. All reagents used were of analytical grade.

Results and Discussion

Table 1: Physiochemical parameters of PMS from different filling stations

Parameters	Density at 15°C	Specific gravity at 15.5 ℃	API gravity	Dynamic viscosity	Kinematic viscosity	Flash point	Cloud point	Pour point
Unit	g cm^{-3}		(^{0})	cP	cSt	^{o}C	^{o}C	^{o}C
DPR Limit	**0.73 (min)**	**0.75**	**57.10**	**0.70**	**1.00**	**28.00**	**-20.00**	**-30.00**

STI	0.72	0.73	62.15	0.60	0.83	29.00	-20.30	-23.93
ST2	0.74	0.75	56.39	0.65	0.87	28.00	-20.03	-23.76
ST3	0.73	0.73	60.57	0.67	0.91	27.80	-19.93	-23.90
ST4	0.72	0.72	62.62	0.70	0.97	27.80	-20.26	-23.73
ST5	0.71	0.72	63.78	0.69	0.96	28.00	-20.23	-24.00
ST6	0.72	0.73	62.22	0.60	0.83	28.00	-20.30	-23.90
ST7	0.72	0.73	61.88	0.61	0.84	28.00	-20.30	-24.03
ST8	0.71	0.72	65.93	0.62	0.87	27.90	-20.10	-24.10
ST9	0.74	0.74	60.05	0.66	0.39	27.90	-20.13	-23.90
ST10	0.73	0.73	63.18	0.64	0.88	28.00	-19.83	-24.06

Results from table 1 show that most of the densities are negligibly below the minimum DPR range of 0.730 – 0.780 g cm^{-3}. The specific gravity and API gravity ranged from 0.72 – 0.75 and 56.39 – 65.93 respectively. This indicates that the gasoline samples are neither too light nor too heavy. The density at 15 ^{o}C, specific gravity at 15.5 ℃ and API gravity are parameters that are indicative of the storage and handling properties of the petroleum fractions under different temperature conditions. In respect to the results of the three parameters, it can be inferred that the handling and the storage of the petroleum fractions (PMS) in a tropical country like Nigeria is not poor. According to Speight (2014), any hydrocarbon liquid with API gravity > 40 ^{o} is paraffinic and volatile. Meanwhile, all the gasoline samples have their API gravity > 55 ^{o} hence are paraffinic and volatile which are good characteristics of PMS.

The dynamic viscosity of PMS from ST4 corresponds to the DPR value of 0.70 cP while the rest are slightly below the DPR limit. The cloud point of the PMS samples are slightly below and above the DPR limits -20.30 – -19.83 while the pour point of the samples are consistently below the DPR value. Cloud point is the temperature at which liquid hydrocarbons begin to form or develop waxes while pour point is the minimum temperature at which a petroleum product under intense cooling loses it flow characteristics or becomes immobile. Generally, petroleum fractions from all the stations had cloud point values within the DPR value of -20.0 °C. This is an indication that the Nigerian PMS can conveniently be used in tropical and temperate countries, whose temperature condition could be extremely cold in the region of -18 °C.

Table 2: Physiochemical parameters of DPK from filling stations at different locations in Makurdi

Parameters	Density at 15°C	Specific gravity at 15.5 ℃	API gravity	Dynamic viscosity	Kinematic viscosity	Flash point	Cloud point	Pour point
Unit	g cm^{-3}		(^{0})	cP	cSt	℃	℃	℃
DPR Limit	**0.82_{min}**	**0.83_{min}**	**41.17**	**1.60**	**2.00**	**50.00**	**-10.00**	**-20.00**
STI	0.78	0.79	46.71	0.96	1.22	50.00	-10.06	-20.06
ST2	0.79	0.79	46.15	1.10	1.39	50.00	-9.90	-32.03
ST3	0.79	0.79	45.68	0.95	1.20	49.50	-10.20	-30.10
ST4	0.78	0.78	48.43	0.96	1.23	51.00	-10.03	-29.03
ST5	0.78	0.78	48.38	0.98	1.25	50.00	-9.96	-29.50
ST6	0.78	0.78	47.09	0.89	1.13	49.50	-10.00	-20.00
ST7	0.79	0.81	44.32	0.96	1.20	49.00	-10.00	-20.00
ST8	0.78	0.78	47.90	0.95	1.22	52.00	-9.96	-29.43
ST9	0.78	0.78	49.53	1.10	1.40	51.00	-9.86	-29.03
ST10	0.79	0.79	48.02	0.99	1.25	50.00	-10.13	-28.46

Table 2 shows that the density of the DPK samples are consistently below the DPR limits but the deviations are insignificant. The slightly lighter fractions will however be relatively more volatile than the standard product, hence burn faster in the appliances used, thus increasing the frequency of usage, which would translate to increased costs for the consumers. The specific gravities of the samples were also found to be slightly lower than the DPR minimum limit of 0.83.

The disparity in values of specific gravity (SG) and density for ST7 could be due to some experimental errors. The API gravity of the samples were all above the DPR value of 41.17 ; an indication that the lower the density, the higher the API gravity and vice versa. The dynamic and kinematic viscosities were significantly below the DPR values of 1.60 and 2.00 respectively, and this deviation could affect the burning rate of the kerosene. Due to lower intermolecular entanglement (viscosity), the DPK samples would exhibit lower wax formation tendencies. The pour point of DPK at stations 6 and 7 also correspond to the DPR value of -20.00 °C while others are below the DPR limit. The values however indicate that the kerosene fractions are of good flow properties.

Table 3: Physiochemical parameters of AGO from filling stations at different locations in Makurdi

Parameters	Density at 15°C	Specific Gravity at 15.5 ℃	API gravity	Dynamic viscosity	Kinematic viscosity	Flash point	Cloud point	Pour point
Unit	g cm^{-3}		(°)	cP	cSt	℃	℃	℃
DPR Limit	**0.82$_{min}$**	**0.85$_{min}$**	**32.95**	**2.60**	**3.00**	**90**	**-5.00**	**-10.0**
STI	0.82	0.83	38.20	2.69	3.26	91	-4.83	-9.20
ST2	0.85	0.85	33.72	2.68	3.16	90	-6.10	-10.06
ST3	0.82	0.83	38.92	2.68	3.26	91	-6.90	-9.96
ST4	0.85	0.86	32.63	2.70	3.16	90	-5.00	-10.00
ST5	0.84	0.85	35.08	2.99	3.26	90	-4.60	-12.46
ST6	0.84	0.85	34.19	2.66	3.55	90	-5.06	-10.03
ST7	0.85	0.86	33.57	2.69	3.18	90	-4.86	-9.80
ST8	0.81	0.82	40.32	2.98	3.18	90	-6.00	-10.83
ST9	0.86	0.86	32.93	3.00	3.66	90	-5.20	-10.16
ST10	0.86	0.86	33.57	2.66	3.49	90	-5.00	-10.00

Table 3 data indicates that the mean value of densities (0.84) of the diesel samples were above the DPR value of 0.82 by ± 0.02. This implies that the density values are not far from the reference hence are incapable of adversely affecting the performance output of the product. Similarly, the mean specific gravity of 0.83 for AGO at stations 1, 3, 5 and 8 deviate from the DPR value of 0.85 by ± 0.02, which means the samples are within the acceptable range. The API gravity of the samples are all above the DPR value of 32.95 ^{o} except samples at stations 4 and 9 which are insignificantly below the DPR value by 0.32 ^{o} and 0.02 ^{o} respectively. All the API gravity values, except that of station 8 are < 40 ^{o}. This goes to confirm that the molecular weight of diesel, a heavier petroleum fraction is indeed higher than those of PMS and DPK. The dynamic and kinematic viscosities of the diesel samples are slightly above the DPR minimum values. The mean values of dynamic viscosity and kinematic viscosity across the ten sampling points are 2.77 ± 0.15 and 3.32 ± 0.18 respectively. These values are not worrisome as are higher than the DPR recommended values by only about 0.17 and 0.32, especially that they may fall within the maximum values. This is because fluids with high a high viscosity index tend to provide more protection to working components of the engine over a wide temperature range. This is achieved by the fluid maintaining its thickness, hence providing the necessary barrier protection between parts that would otherwise result to wear due to metal–to–metal contacts.

AGO at stations 4 and 10 cloud point values corresponds to the DPR value of -5.00 ^{o}C, while that at stations 1,5,7 are slightly below the DPR value by -0.4 ^{o}C and below. The AGO at stations 2, 3,6,8,9 are above the DPR value. The diesel samples at stations 4 and 10 have their pour points corresponding to the DPR value, that at stations 2 and 6 are a little above the DPR by +0.06 ^{o}C and +0.03 ^{o}C respectively; those at stations 1,3,5 are slightly below the DPR value.

Table 4: Physiochemical parameters of lube oil from filling stations at different locations in Makurdi

Parameters	Density at 15°C	Specific Gravity at 15.5 ℃	API gravity	Dynamic viscosity	Kinematic viscosity	Flash point	Cloud point	Pour point
Unit	g cm^{-3}		(^{o})	cP	cSt	℃	℃	℃
DPR Limit	**0.87**	**0.850_{min}**	**29.78**	**21.00_{max}**	**19.80**	**224.00_{max}**	**7.00**	**2.00**
STI	0.88	0.89	27.41	47.40	53.88	223.00	6.80	1.80
ST2	0.88	0.89	27.23	46.50	52.80	224.00	7.03	2.03
ST3	0.88	0.89	32.21	46.60	52.96	223.00	7.06	2.10
ST4	0.85	0.86	31.51	47.00	54.99	223.50	6.16	1.63
ST5	0.86	0.87	28.13	45.50	53.08	224.00	8.02	3.10
ST6	0.88	0.88	28.42	47.30	53.97	224.00	8.16	3.10
ST7	0.88	0.88	28.42	46.90	53.01	224.00	8.10	3.03
ST8	0.88	0.88	28.69	48.00	54.41	224.00	7.60	2.36
ST9	0.88	0.83	38.76	47.50	53.79	224.00	6.86	1.93
ST10	0.88	0.88	28.26	47.20	53.36	224.90	7.00	2.00

From table 4; the density of the lube oil at stations 4 and 5 are below the DPR value by -0.0184 ^{o} and -0.0159 ^{o} difference, the rest of the samples are a little above the DPR value by +0.0066 ^{o}. The DPR specification for specific gravity of lube oil is 0.8500 – 0.9500. The specific gravity obtained therefore are all within the DPR range except lube oil at station 9 which is slightly below the DPR value. Stations 1 – 3 have API gravity a little below the DPR value of 29.78 ^{o}; those at stations 4 – 5 and 9 are a little above the DPR value at the difference of more or less +2.43 ^{o}; while those at stations 6 – 8 and 10 just below the DPR value at the difference of more or less -1.52 ^{o}. Dynamic viscosities of the lube oil samples are highly above the DPR value at the difference of more or less +26.4 cP. Also the kinematic viscosities of the samples are far above the DPR value by +34.38; these may be attributable to storage facilities, transportation or handling and possibly an act of adulteration. This on the other hand agrees with the fact that all lubricants are heavy oils and viscous. Lube oil at station 10 has it cloud point corresponds to the DPR value of 7.00, those at stations 2 and 3 have cloud points values a little above the DPR value with the difference of +0.03 ^{o}C and +0.06 ^{o}C. Lube oil at station 1, 4, 9 have value slightly below the DPR value at the difference of more or less -0.02 ^{o}C. Lube oil at station 5, 6, 7 are above the DPR value. The pour point of those at station 10 corresponds to the DPR value of 2.00, while others are below and others above the DPR value. Pour point can also be considered as the lowest temperature at which oil cannot be used as a lubricant. Looking at the pour point values however, it is certain that the lubricants are good for lubrication.

CONCLUSION

The parameters of the petroleum fractions had most of their results slightly deviating from the DPR limits. Despite the fact that some samples fell within the DPR specifications and the slight deviations observed in most of the samples for cannot be under estimated. In view of this, the slight fall in purity of the products may be attributed to the kind of storage facilities, transport facilities, dirt invasion, moisture attack and adulteration. However, petroleum products used in Makurdi metropolis can be conveniently used in other tropical countries as well as in temperate countries with temperature condition of -18 ^{o}C.

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