



## Effects of Petroleum Condensate / Diesel Mixture on Diesel Engines

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### Abstract

*Seven combustible mixtures of condensate / diesel were evaluated with the aim to delimit the extent at which the adulteration of automotive gas oil (AGO) with condensate samples from two different sources becomes hazardous to Diesel engines. Results of the quality assurance test (low CN (cetane number), low boiling point (IBP (initial boiling point), FBP (final boiling point), TR (total recovery)) ranges of atmospheric distillation, high cloud point) show that 4 – 100 % (v/v) of condensate in the adulterated blends are undesirable for diesel engines. Blending condensates in diesel, results in black diesel smoke from inadequate air / fuel mixing in the cylinder with locally over-rich zones, higher fuel injection rates, dirty injectors and injection nozzle tip wear resulting from over use can lead to locally over-rich zones in the combustion chamber.*

**Keywords:** Blending, volatility, Polyaromatic hydrocarbon (PAH), Total petroleum hydrocarbon (TPH), Benzene, toluene, ethylbenzene, xylene (BTEX), biodiesel, persulphate, non-ionic surfactant, combustion quality, total recovery, standard deviation, combustion quality, American standard for testing Materials (ASTM), diesel engine, adulterants, gbaran-15 and uturuogu FI condensates, petroleum product, quality assurance parameter.

### Introduction

In Nigeria, a considerable recoverable reserve of Petroleum condensates (reservoir gases that condense to colorless or light yellow hydrocarbons when produced) has been discovered in the Niger Delta, the most significant hydrocarbon province in the West African continental margin. Condensates from this region have been characterized as highly combustible with an API (American Petroleum Institute) gravity generally higher than 55<sup>0</sup> at a temperature of 15.6<sup>0</sup> C and normal atmospheric pressure. They also have a gas/oil ratio (GOR) exceeding 5000 standard cubic feet per barrel of oil (scf/bbl). They are mainly composed of saturated hydrocarbons in the light range (butanes, pentanes and hexanes). However, condensates with a high percentage of aromatic or naphthenic hydrocarbons have been found in the basins of the Gulf Coast, Canada, Russia and Israel. Such condensates are superior to the typical paraffinic type as gasoline feedstock<sup>1-4</sup>. Aromatic Condensates are formed by evaporative fractionation during vertical migration particularly in deltas. Different in composition from condensate is 'diesel' otherwise known as 'Automotive Gas Oil' it is a hydrocarbon mixture, obtained from the fractional distillation of crude oil between 200<sup>0</sup>C and 350<sup>0</sup>C at atmospheric pressure. The density of petroleum diesel is about 0.85kg/l (7.09lbs/gallon (ns), about 18% more than (gasoline) which has a density of 0.72kg/l (6.0l lbs/gallon (US). When burnt, diesel typically releases about 38.6MJ/L (138,700BTU per US gallon) whereas gasoline releases 34.9MJ/L (125000BTU per US gallon), 10% less by energy density, but 45.41MJ/KG and 48.47MJ/KG, 6.7% more by specific energy<sup>5</sup>. Diesel is generally simpler to refine from petroleum than gasoline. The price of diesel traditionally rises during colder months as demand for heating oil rises, which is refined in much the same way. Due to its higher level of

pollutants, diesel must undergo additional filtration which sometimes contributes to a higher cost. In many parts of the United States and throughout the UK and Australia, diesel may be priced higher than gasoline<sup>6</sup>. Reasons for higher price diesel include the shutdown of some refineries in the Gulf of Mexico, diversion of mass refining capacity to gasoline production and a recent transfer to ultra-low sulfur diesel (ULSD), which causes infrastructural complications<sup>7</sup>. Unlike petroleum ether and liquefied petroleum gas engines, diesel engines do not use high voltage spark ignition (spark plugs). An engine running on diesel compresses the air inside the cylinder to high pressures and temperatures (compression ratios from 15:1 to 21:1 are common)<sup>8</sup>. Diesel is generally injected directly into the cylinder near the end of the compression stroke. The high temperatures inside the cylinder causes the diesel fuel to react with the oxygen in the mix (burn or oxidize), heating and expanding the burning mixture in order to convert the thermal/pressure difference into mechanical work in order to move the piston<sup>9</sup>. High compression ratios and throttle less operation generally result in diesel engines being more efficient than spark-ignited engines<sup>10</sup>. Petroleum-derived diesel is composed of about 75% saturated hydrocarbons (primarily paraffins including n, ISO and cycloparaffins), and 25% aromatic hydrocarbons (including naphthalenes and alkylbenzenes). The average chemical formula for common diesel fuel is C<sub>12</sub>H<sub>23</sub> ranging from approximately C<sub>10</sub>H<sub>20</sub> to C<sub>15</sub>H<sub>28</sub><sup>11</sup>. It is critical Diesel-powered cars generally have a better fuel economy than equivalent gasoline engines and produce less green house gas emission. Their greater economy is due to the higher energy per-litre content of diesel fuel and the intrinsic efficiency of the diesel engine. While petrodiesel's higher density results in higher green house gas emissions per litre compared to gasoline, the 20 – 40% better fuel economy

achieved by modern diesel-engined automobiles offsets the higher-per-litre emissions of greenhouse gases and produces 10 – 20 percent less greenhouse gas emissions than comparable gasoline vehicles<sup>12</sup>. The fact that a few nations together produce the bulk of petroleum has led to high price fluctuation and uncertainties in supply for the consuming nations. This in turn has led them to look for alternative fuels that they themselves can produce. Biodiesel is an alternative fuel made from renewable biological sources such as vegetable oils both (edible and non edible oil) and animal fat<sup>13</sup>. Biodiesel-powered diesel engines offer substantially improved emission reductions compared to petro-diesel or gasoline-powered engines, while retaining most of the fuel economy advantages over conventional gasoline-powered automobiles<sup>9</sup>.

The blending of kerosene into automotive diesel fuel is widely and legitimately practiced by oil industry worldwide as a means of adjusting the low temperature operability of the fuel. This practice is not harmful or detrimental to tailpipe emissions, provided the resulting fuel continues to meet engine manufacturer's specifications (especially for viscosity and cetane number)<sup>14</sup>. However, high-level adulteration of low sulphur (for example, 0.05 percent) diesel fuel with higher-level condensates can cause the fuel to exceed the sulphur maximum<sup>12</sup>. Poly-aromatic hydrocarbons (PAHs) and nitrogen-containing poly-aromatic hydrocarbon (PAHs) in diesel exhaust arise primarily from a "flow-through" effect from the PAHs in the fuel composition. These group of hydrocarbons (PAHs) as well as other hydrocarbons loosely grouped into the aliphatics called Total petroleum hydrocarbon (TPH) and the aromatic classed into benzene, toluene, ethylbenzene and xylene (BTEX) are ubiquitous in crude oil and they have been found to be susceptible to persulphates<sup>15</sup>. Petrodiesel-Biodiesel blends are products most commonly distributed for use in the retail diesel fuel market. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix. For instance 100 % biodiesel is referred to as B100<sup>16</sup>. The exhaust emissions of carbon monoxide, unburned hydrocarbons and particulate emission from biodiesel are lower than fossil fuel.<sup>17</sup> Blending condensates in diesel, results in black diesel smoke from inadequate air / fuel mixing in the cylinder with locally over-rich zones. Higher fuel injection rates, dirty injectors and injection nozzle tip wear resulting from over use can lead to locally over-rich zones in the combustion chamber<sup>7</sup>. Over-fueling to increase power output, a common phenomenon worldwide, results in higher smoke emissions and lower fuel economy<sup>14</sup>. Dirty injectors are common because injector maintenance is costly in terms of actual repair costs and downtime consequential losses<sup>18</sup>.

Our group attempted to characterize some condensate samples from two gas reservoirs, namely; Gbaran gas field, owned and controlled by SPDC, located in Bayelsa State of the Niger Delta and Utoruogu gas field owned and controlled by Chevron/Texaco located in Delta State still of the Niger Delta. Condensates were obtained from two wells within each reservoir. Experiments were carried out in this study to discover

how and if the sources of these condensates affect their characteristics as well as their effect when used as adulterants on petroleum products. The essence of obtaining condensates from specific wells and comparing their effects on condensates from other wells and reservoirs is also to ensure repeatability and reproducibility. We used bulk quality assurance parameters such as Cetane number, gravity (specific and API), distillation profile and cloud point to assess the quality of the condensate / adulterated diesel. Our aim is to determine the extent at which such adulterations become hazardous to diesel engines, by implication, we shall attempt to expose the defects of the adulterated product and where they are none, to increase the quality assurance and trust of consumer.

## Material and Methods

Petro diesel (Automotive gas oil, AGO) was collected from the Nigerian National Petroleum Corporation (NNPC) while the petroleum condensate samples were collected from Gbaran and Utoruogu reservoirs of the Niger Delta Nigeria.

**Blending of Condensate/Ago Samples:** Test samples (condensate / AGO mixtures) were blended into 7 different proportions (ie pure AGO, pure condensate and 1, 2, 3, 4, 5 % (v/v) condensate / AGO blend. The blends and pure samples were refrigerated at 35<sup>o</sup> F (2<sup>o</sup>C) to avoid evaporation of volatile components<sup>2</sup>.

**Determination of Cetane Number of Condensate/Ago Samples:** A 100 ml of the sample is injected into a constant volume combustion chamber in which the ambient temperature is approximately 575°C. The fuel combusts and the high rate of pressure change within the chamber defines the start of combustion. The ignition delay of the fuel which is a function of the cetane number of the fuel can then be calculated as the time difference between the start of fuel injection and the start of combustion<sup>19</sup>.

**Evaluation of Condensate/Ago Samples by Atmospheric Distillation:** A 100 ml portion of the test condensate / AGO sample was measured with a 100 ml graduated cylinder and was poured into a round bottom flask containing some boiling stones to prevent explosion. Readings were obtained for the initial boiling point (IBP) temp., 10 ml and 50 ml recovery temp., the final boiling point (FBP) temperature and the total recovery temperature.<sup>1</sup>

**Determination of the Specific Gravity of Condensate/Ago Samples:** The specific gravity of diesel and blended samples were determined by the ASTM test Method (D1298/IP 160). A 400 ml graduated cylinder was filled with the sample to be analyzed. A hydrometer with calibrations of 0.70 or 0.75 was submerged into it. Readings were taken as the hydrometer floats on the sample. A thermometer was then inserted into the graduated cylinder for 10 s and the temp. recorded. Specific gravity values corresponding to the temperature in <sup>o</sup>C were read as values for the corrected specific gravity<sup>20</sup>.

**Determination of the Cloud Point of Condensate / Ago Samples:** Pour 100 ml of the sample into the test jar to the level mark. Close the test jar tightly by the cork carrying the test thermometer. Adjust the position of the cork and the thermometer so that the cork fits tightly, the thermometer and the jar are coaxial, and the thermometer bulb is resting on the bottom of the jar. Place the gasket around the test jar, 25 mm from the bottom. Insert the test jar in the jacket. Never place a jar directly into the cooling medium. The specimen is cooled at a specified rate and examined periodically. The temperature at which a cloud is first observed at the bottom of the test jar is recorded as the cloud point. Report the cloud point, to the nearest 1°C, at which any cloud is observed at the bottom of the test jar, which is confirmed by continued cooling<sup>21</sup>.

**Results and Discussion**

**Cetane Number of Diesel (Ago) and Blended Samples:** The Cetane number of diesel (AGO), Condensate and Condensate /AGO blended samples were obtained in tables 1. Tables 1 show

the cetane numbers of Gbaran-15(1) and Gbaran-15(2) condensate as well as their condensate / AGO blended samples. According to ASTM, the minimum cetane number of AGO desirable for diesel engines is 46<sup>16</sup>. Table 1 show that only a maximum of 2 % Gbaran-15(1) and Gbaran-15(2) condensate could pass the cetane number test when blended with AGO, this implies that AGO blended with up to 3 % of the condensate from the Gbaran-15 reservoir will cause a lot of damages to diesel engines. On the other hand, up to 3 % of the condensates obtained from the Utoruogu reservoir passed the cetane number test when blended with AGO. This draws the inference that condensates from Utoruogu reservoir has a better effect on the cetane number on the AGO used for this study than condensates from Gbaran-15 reservoir. Table 1 also shows the level of deviation obtained after blending AGO with different proportion of condensates. The higher the amount of condensate blended with AGO, the higher the deviation from the cetane number of pure AGO.

**Table-1**  
**Cetane Number of Ago and Condensate/Ago Blended Samples**

| Pet. Pr. | CN | X-CN | (X-CN) <sup>2</sup> | (X-CN) <sup>2</sup> /25 | ST. DEV. |
|----------|----|------|---------------------|-------------------------|----------|
| AGO      | 55 | 0    | 0                   | 0                       | 0        |
| GB-15(1) | 18 | -37  | 1369                | 54.76                   | 7.4      |
| 1:99%    | 52 | -3   | 9                   | 0.36                    | 0.6      |
| 2:98%    | 47 | -8   | 64                  | 2.56                    | 1.6      |
| 3:97%    | 42 | -13  | 169                 | 6.76                    | 2.6      |
| 4:96%    | 37 | -18  | 324                 | 12.96                   | 3.6      |
| 5:95%    | 32 | -23  | 529                 | 21.16                   | 4.6      |
| GB-15(2) | 18 | -37  | 1369                | 54.76                   | 7.4      |
| 1:99%    | 50 | -5   | 25                  | 1                       | 1        |
| 2:98%    | 45 | -10  | 100                 | 4                       | 2        |
| 3:97%    | 42 | -13  | 169                 | 6.76                    | 2.6      |
| 4:96%    | 39 | -16  | 256                 | 10.24                   | 3.2      |
| 5:95%    | 34 | -21  | 441                 | 17.64                   | 4.2      |
| UT FI(1) | 20 | -35  | 1225                | 49                      | 7        |
| 1:99%    | 53 | -2   | 4                   | 0.16                    | 0.4      |
| 2:98%    | 50 | -5   | 25                  | 1                       | 1        |
| 3:97%    | 46 | -9   | 81                  | 3.24                    | 1.8      |
| 4:96%    | 42 | -13  | 169                 | 6.76                    | 2.6      |
| 5:95%    | 37 | -18  | 324                 | 12.96                   | 3.6      |
| UT FI(2) | 20 | -35  | 1225                | 49                      | 7        |
| 1:99%    | 53 | -2   | 4                   | 0.16                    | 0.4      |
| 2:98%    | 50 | -5   | 25                  | 1                       | 1        |
| 3:97%    | 46 | -9   | 81                  | 3.24                    | 1.8      |
| 4:96%    | 37 | -18  | 324                 | 12.96                   | 3.6      |
| 5:95%    | 37 | -18  | 324                 | 12.96                   | 3.6      |

**Atmospheric Distillation of Diesel (Ago) and Blended Samples:** The results of the atmospheric distillation of the test diesel vs. Condensate/diesel blends are given in tables 2, 3, 4 and 5. Tables 2 and 3 show distillation profile of AGO blended with Gbaran-15(1) and Gbaran-15(2) condensates respectively while tables 4 and 5 show distillation profile of AGO blended with Utoruogu-FI(1) and Utoruogu-FI(2) condensates respectively. The pure diesel (=Automotive gas oil =AGO; unblended) had a 10 ml recovery temperature of 268<sup>o</sup>C, which is far below the maximum temperature of 280<sup>o</sup>C specified by the American Society for Testing and Materials<sup>17</sup>. The total recovery (TR) of 98ml and 50ml recovery at 298<sup>o</sup>C as well as a final boiling point (FBP) of 360<sup>o</sup>C. Obtained for AGO were also within the standard specifications. According to the ASTM, the limits specified for 50ml recovery and the FBP should not be below 285<sup>o</sup>C and 345<sup>o</sup>C, respectively. From tables 2 and 3 it can be deduced that 5:95, and 4:96 mixtures (v/v) of the adulterated Gbaran-15 condensate/AGO blends were not within the ASTM-

specified maxima, which imply that these blends will cause a lot of problems to diesel engines. However, the 1:99, 2:98 and 3:97 Gbaran-15 condensate/AGO blends had an average 50 ml recovery temperature of 296<sup>o</sup>C, 290<sup>o</sup>C and 289<sup>o</sup>C respectively and a FBP of 352<sup>o</sup>C, 348<sup>o</sup>C and 346<sup>o</sup>C respectively which are within the standard maxima; the 10ml recovery was also below the 280<sup>o</sup>C maximum. These results show that only an adulteration in the proportion 1:99, 2:98 and 3:97 Gbaran-15 condensate/AGO blends, will auto-ignite without much damage to the diesel engine. In a situation of reduced diesel supply and increase demand, it is only an adulteration of pure diesel with a maximum of 3% of the Gbaran-15 condensate will be permissible. On the other hand, tables 4 and 5 show that the 1:99, 2:98 and 3:97 Utoruogu FI condensate/AGO blends had an average 50 ml recovery temperature of 297<sup>o</sup>C, 291<sup>o</sup>C and 288<sup>o</sup>C respectively and a FBP of 360<sup>o</sup>C, 360<sup>o</sup>C and 349<sup>o</sup>C respectively which are within the standard maxima.

**Table-2**  
**Distillation Profile of Ago (<sup>o</sup>C), Gbaran-15(1) Condensate and Gbaran-15(1) Condensate/Ago Blended Samples**

| Volume distilled (ml) | Rec.Temp. ( <sup>o</sup> C) AGO | Recovery temp. ( <sup>o</sup> C) of adulterated condensate/AGO blends |         |         |          |          |         |
|-----------------------|---------------------------------|---|---------|---------|----------|----------|---------|
|                       |                                 | Cond.   | 1:99(%) | 2:98(%) | 3:97 (%) | 4:96 (%) | 5:95(%) |
| IBP                   | 220                             | 74  | 128     | 125     | 124      | 124      | 120     |
| 10                    | 268                             | 106   | 266     | 262     | 260      | 259      | 250     |
| 20                    | 275                             | 115   | 270     | 270     | 270      | 265      | 261     |
| 30                    | 282                             | 125   | 280     | 276     | 275      | 272      | 270     |
| 40                    | 290                             | 134   | 290     | 284     | 284      | 280      | 279     |
| 50                    | 298                             | 145   | 296     | 290     | 289      | 286      | 283     |
| 60                    | 300                             | 160   | 300     | 295     | 295      | 293      | 290     |
| 70                    | 315                             | 176   | 310     | 305     | 305      | 304      | 300     |
| 80                    | 325                             | 197   | 318     | 311     | 310      | 307      | 302     |
| 90                    | 346                             | 225   | 342     | 335     | 333      | 319      | 315     |
| FBP                   | 360                             | 274   | 352     | 348     | 346      | 343      | 340     |
| TR                    | 98ml                            | 98ml  | 98ml    | 98ml    | 98ml     | 98ml     | 98ml    |

AGO = Automotive gas oil, IBP = Initial boiling point, FBP = final boiling point, total recovery, Cond. = Condensate

**Table-3**  
**Distillation Profile of Ago (<sup>o</sup>C), Gbaran-15(2) Condensate and Gbaran-15(2) Condensate/Ago Blended Samples**

| Volume distilled (ml) | Rec.Temp. ( <sup>o</sup> C) AGO | Recovery temp. ( <sup>o</sup> C) of adulterated condensate/AGO blends |         |         |          |          |         |
|-----------------------|---------------------------------|---|---------|---------|----------|----------|---------|
|                       |                                 | Cond.   | 1:99(%) | 2:98(%) | 3:97 (%) | 4:96 (%) | 5:95(%) |
| IBP                   | 220                             | 74  | 130     | 125     | 124      | 124      | 122     |
| 10                    | 268                             | 106   | 267     | 264     | 260      | 259      | 252     |
| 20                    | 275                             | 115   | 270     | 270     | 271      | 265      | 261     |
| 30                    | 282                             | 123   | 280     | 276     | 275      | 272      | 270     |
| 40                    | 290                             | 135   | 290     | 284     | 284      | 281      | 279     |
| 50                    | 298                             | 145   | 296     | 290     | 289      | 286      | 283     |
| 60                    | 300                             | 160   | 301     | 296     | 295      | 293      | 290     |
| 70                    | 315                             | 177   | 310     | 305     | 305      | 304      | 301     |
| 80                    | 325                             | 195   | 318     | 311     | 310      | 307      | 302     |
| 90                    | 346                             | 224   | 342     | 335     | 333      | 319      | 315     |
| FBP                   | 360                             | 277   | 353     | 348     | 346      | 343      | 340     |
| TR                    | 98ml                            | 97ml  | 96ml    | 98ml    | 98ml     | 97ml     | 98ml    |

AGO = Automotive gas oil, IBP = Initial boiling point, FBP = final boiling point, total recovery, Cond. = Condensate

**Table-4**  
**Distillation Profile of Ago (<sup>o</sup>c), Utoruogu Fi (1) Condensate and Utoruogu Fi (1) Condensate/Ago Blended Samples**

| Volume distilled (ml) | Rec.Temp. ( <sup>o</sup> C) AGO | Recovery temp. ( <sup>o</sup> C) of adulterated condensate/AGO blends |         |         |          |          |         |
|-----------------------|---------------------------------|---|---------|---------|----------|----------|---------|
|                       |                                 | Cond  | 1:99(%) | 2:98(%) | 3:97 (%) | 4:96 (%) | 5:95(%) |
| IBP                   | 220                             | 45  | 139     | 133     | 129      | 126      | 124     |
| 10                    | 268                             | 81  | 275     | 270     | 266      | 262      | 258     |
| 20                    | 275                             | 100   | 281     | 278     | 274      | 269      | 263     |
| 30                    | 282                             | 111   | 293     | 285     | 280      | 276      | 272     |
| 40                    | 290                             | 120   | 297     | 291     | 288      | 283      | 280     |
| 50                    | 298                             | 133   | 304     | 296     | 292      | 289      | 286     |
| 60                    | 300                             | 149   | 314     | 305     | 300      | 297      | 294     |
| 70                    | 315                             | 165   | 321     | 315     | 311      | 309      | 305     |
| 80                    | 325                             | 196   | 330     | 329     | 314      | 319      | 315     |
| 90                    | 346                             | 225   | 344     | 339     | 337      | 328      | 318     |
| FBP                   | 360                             | 279   | 360     | 360     | 349      | 345      | 342     |
| TR                    | 97ml                            | 97ml  | 98ml    | 98ml    | 98ml     | 97ml     | 98ml    |

AGO = Automotive gas oil, IBP = Initial boiling point, FBP = final boiling point, total recovery, Cond. = Condensate

**Table-5**  
**Distillation Profile Of Ago (<sup>o</sup>c), Utoruogu Fi (2) Condensate and Utoruogu Fi (2) Condensate/Ago Blended Samples**

| Volume distilled (ml) | Rec.Temp. ( <sup>o</sup> C) AGO | Recovery temp. ( <sup>o</sup> C) of adulterated condensate/AGO blends |         |         |          |          |         |
|-----------------------|---------------------------------|---|---------|---------|----------|----------|---------|
|                       |                                 | Cond.   | 1:99(%) | 2:98(%) | 3:97 (%) | 4:96 (%) | 5:95(%) |
| IBP                   | 222                             | 45  | 137     | 132     | 129      | 126      | 125     |
| 10                    | 267                             | 81  | 275     | 270     | 266      | 262      | 258     |
| 20                    | 275                             | 100   | 281     | 278     | 274      | 269      | 263     |
| 30                    | 282                             | 111   | 293     | 285     | 280      | 276      | 272     |
| 40                    | 290                             | 120   | 297     | 291     | 288      | 283      | 280     |
| 50                    | 298                             | 132   | 304     | 296     | 292      | 289      | 286     |
| 60                    | 300                             | 150   | 314     | 304     | 301      | 297      | 294     |
| 70                    | 315                             | 165   | 321     | 315     | 311      | 309      | 305     |
| 80                    | 325                             | 196   | 330     | 329     | 314      | 319      | 315     |
| 90                    | 346                             | 225   | 344     | 339     | 334      | 328      | 318     |
| FBP                   | 360                             | 279   | 360     | 360     | 349      | 345      | 342     |

AGO = Automotive gas oil, IBP = Initial boiling point, FBP = final boiling point, total recovery, Cond. = Condensate

**Specific Gravity of Diesel (Ago) and Blended Samples:** The specific gravity and weighted equivalent on the American Petroleum Institute (API) gravity scale of the control samples and adulterated Gbaran-15(1) condensate/AGO blends are collected in table 6. With reference to these results, Gbaran-15(1) condensate and the adulterated AGO samples had a specific gravity in the range of 0.86 - 0.87 (i.e of 31.09 – 31.22 API gravity). An AGO sample with a specific gravity value less than 0.87, will result in black diesel smoke from inadequate air / fuel mixing in the cylinder with locally over-rich zones<sup>18</sup>. Only a condensate/AGO blend of 2:98 can pass the specific gravity test. Comparing this with the specific gravity of Gbaran-15(2), Utoruogu-FI(1) and Utoruogu-FI(2) condensates with their condensate / AGO blends it can be deduced that the specific gravities of Gbaran-15(1) condensate / AGO blends, Gbaran-15(2) condensate / AGO blends, Utoruogu-FI(1) condensate / AGO blends and Utoruogu-FI(2) condensate / AGO blends, fall within the same range. Table 6 also shows the level of

deviation obtained in terms of specific gravity after blending AGO with different proportions of condensate.

**Cloud Point of Diesel (Ago) and Blended Samples:** The cloud point of AGO, condensate and adulterated condensate/AGO blends are given in table 7. From these tables it can be deduced that the cloud point of AGO increases with increase in the amount of Condensate added. This will not be unconnected with the fact that condensates have higher paraffin content than AGO, which is responsible for its wax formation. Since cloud point is a function of a cooling effect (reduced temperature), it follows that samples with higher cloud points form a cloudy appearance faster than the ones with lower cloud points. It is critical to regulate the wax content of diesel to forestall operational problems just as is obtainable in the use of press mud to regulate water holding capacity of the soil. Press muds are used both as a soil reclamation agent as well as a soil conditioner<sup>22</sup>. Inasmuch as the increase in the cloud point of diesel above acceptable levels can cause handling problems,

little amount of condensates can be used to boost the waxy content of diesels with very low cloud points. According to ASTM, the maximum acceptable cloud point for AGO is 3 °C. Cloud points formed at temperatures above that indicates that the sample has a high waxy content it will definitely cause a lot of operational and handling problems<sup>23</sup>. It can also be deduced from the Table that the maximum amount of condensate that can pass the cloud point test irrespective of the source (Gbaran or Utoruogu) according to ASTM is 3 %. AGO blended with condensates from either Gbaran or Utoruogu reservoir above 3

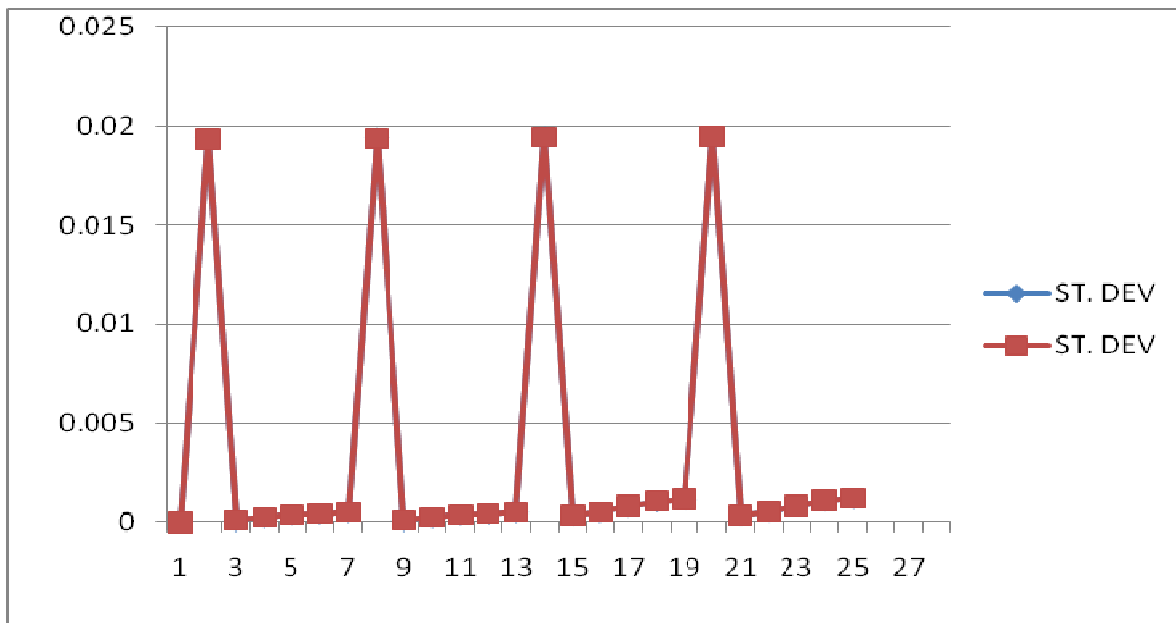
% will definitely cloud too fast thereby having a higher tendency of plugging filters and small orifices. Samples with the tendency of clouding faster than the specified temperature as stipulated by ASTM contains particles or substances that make them precipitate and form wax faster than anticipated. This Table also show that all the condensate used in this study have a cloud point of 12°C which is obviously above the ASTM maxima. The control sample (pure AGO) has a cloud point of -6°C, which is within ASTM maxima.

**Table-6**  
**Specific Gravity of Ago, Condensate, Condensate/Ago Blended Samples**

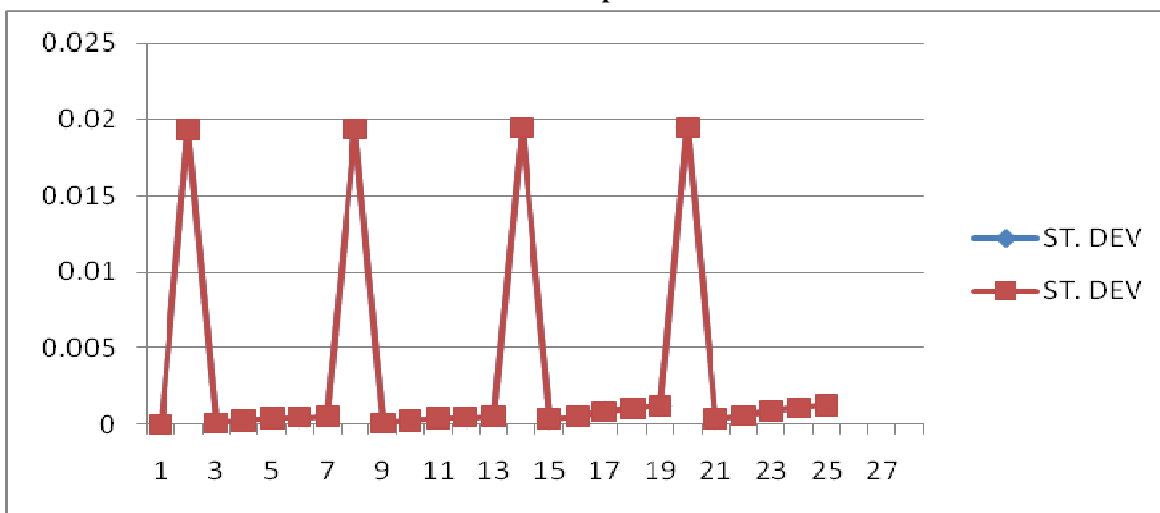
| Pet. Pr. | SG     | X-SG    | (X-SG)2  | (X-SG)2/25 | ST. DEV |
|----------|--------|---------|----------|------------|---------|
| AGO      | 0.8708 | 00      | 00       | 00         | 00      |
| GB-15(1) | 0.7739 | -0.0969 | 0.00939  | 0.00037558 | 0.01936 |
| 1:99%    | 0.8703 | -0.0005 | 2.5E-07  | 1E-08      | 0.0001  |
| 2:98%    | 0.8696 | -0.0012 | 1.44E-06 | 5.76E-08   | 0.00024 |
| 3:97%    | 0.8689 | -0.0019 | 3.61E-06 | 1.444E-07  | 0.00038 |
| 4:96%    | 0.8686 | -0.0022 | 4.84E-06 | 1.936E-07  | 0.00044 |
| 5:95%    | 0.8682 | -0.0026 | 6.76E-06 | 2.704E-07  | 0.00052 |
| GB-15(2) | 0.7739 | -0.0969 | 0.00939  | 0.00037558 | 0.01938 |
| 1:99%    | 0.8703 | -0.0005 | 2.5E-07  | 1E-08      | 0.0001  |
| 2:98%    | 0.8696 | -0.0012 | 1.44E-06 | 5.76E-08   | 0.00024 |
| 3:97%    | 0.8689 | -0.0019 | 3.61E-06 | 1.444E-07  | 0.00038 |
| 4:96%    | 0.8686 | -0.0022 | 4.84E-06 | 1.936E-07  | 0.00044 |
| 5:95%    | 0.8682 | -0.0026 | 6.76E-06 | 2.704E-07  | 0.00052 |
| UT FI(1) | 0.7735 | -0.0973 | 0.009467 | 0.00037869 | 0.01946 |
| 1:99%    | 0.8691 | -0.0017 | 2.89E-06 | 1.156E-07  | 0.00034 |
| 2:98%    | 0.8682 | -0.0026 | 6.76E-06 | 2.704E-07  | 0.00052 |
| 3:97%    | 0.8667 | -0.0041 | 1.68E-05 | 6.724E-07  | 0.00082 |
| 4:96%    | 0.8655 | -0.0053 | 2.81E-05 | 1.1236E-06 | 0.00106 |
| 5:95%    | 0.8649 | -0.0059 | 3.48E-05 | 1.3924E-06 | 0.00118 |
| UT FI(2) | 0.7734 | -0.0974 | 0.009487 | 0.00037947 | 0.01948 |
| 1:99%    | 0.8691 | -0.0017 | 2.89E-06 | 1.156E-07  | 0.00034 |
| 2:98%    | 0.8681 | -0.0027 | 7.29E-06 | 2.916E-07  | 0.00054 |
| 3:97%    | 0.8666 | -0.0042 | 1.76E-05 | 7.056E-07  | 0.00084 |
| 4:96%    | 0.8653 | -0.0055 | 3.03E-05 | 1.21E-06   | 0.0011  |
| 5:95%    | 0.8647 | -0.0061 | 3.72E-05 | 1.4884E-06 | 0.00122 |

**Table-7**  
**Cloud Point of Ago and Condensate/Ago Blended Samples**

| COND / AGO BLENDS    | AGO   | COND  | 1:99(%) | 2:98(%) | 3:97(%) | 4:96(%) | 5:95(%) |
|----------------------|-------|-------|---------|---------|---------|---------|---------|
| GBARAN-15(1) / AGO   | -6 °C | 12 °C | -3 °C   | 0 °C    | 3 °C    | 4.5 °C  | 6.0 °C  |
| GBARAN-15(2) / AGO   | -6 °C | 12 °C | -3 °C   | 0 °C    | 3 °C    | 4.5 °C  | 6.0 °C  |
| UTORUOGU FI(1) / AGO | -6 °C | 12 °C | -3 °C   | 0 °C    | 3 °C    | 4.5 °C  | 6.0 °C  |
| UTORUOGU FI(2) / AGO | -6 °C | 12 °C | -3 °C   | 0 °C    | 3 °C    | 4.5 °C  | 6.0 °C  |



**Figure-1**  
 Standard Deviation Graph for Cetane Number



**Figure-2**  
 Standard Deviation Graph for Specific Gravity

### Conclusion

The quality assurance parameters considered in this study are very key in choosing diesel suitable for diesel engines. The volatility and combustion quality of diesel are of utmost importance in determining the quality of diesel. The combustion quality of diesel is measured in terms of the cetane rating while the volatility is measured in terms of distillation, specific gravity and cloud point. The volatility characteristic of the condensates used in this study were unaffected by the sources of condensate, however the combustion quality of condensate from Utoruogu reservoir tend to have a better ignition delay (cetane rating ) than those from Gbaran reservoir. An assessment of our results

points to the undesirability of the adulterated Gbaran condensate / diesel and Utoruogu condensate / diesel blends for diesel engines, especially in the case of 4 – 100 % (v/v) condensate / diesel blends. This is due to the low cetane rating, low boiling point (initial boiling point (IBP), final boiling point (FBP), total recovery (TR) ranges of atmospheric distillation and high cloud point of the adulterated blends.

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