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RESEARCH PAPER

Specification and Evaluation of Diesel Fuel used in Electricity Generation in Erbil

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A B S T R A C T:

Two sets of diesel samples, which include fifty samples in both winter and summer seasons, from electricity generators in different locations in Erbil city (Kurdistan reign-Iraq) were investigated. Another additional diesel sample, which was obtained from the directly fractional distillation of Khurmala oilfield near Erbil city was also investigated. The samples were evaluated and compared their sulfur content, flash point, density (API), pour point, aniline point, cetane number and distillation curves with worldwide guidelines. It was observed from the evaluation of these samples that most of the diesel samples have higher sulfur content, lower flash point, higher pour point, lower cetane number, naphthenic character and have low IBP, low 10% distillation temperature, normal 50% distillation temperature and Final Boiling point (FBP). While the diesel fuel obtained from the fractional distillation of Khurmala crude oil gave acceptable values in all specification tests according to Iraqi guideline.

KEY WORDS: Diesel, Khurmala oilfield, API, Flash Point, Cetane number.
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1. INTRODUCTION

Due to larger efficiency, reliability, high energy output and gasoline economy, the commercial transportation sector and electric producer station utilize diesel fuels which are the most dominant oils (Nadeem *et al.*, 2006). Whereas, the distillation of crude oil makes Diesel fuel that is totally complicated of a mixture of hydrocarbons. There are hydrocarbons in diesel fuels consisting of four types which are paraffin, naphthenic, olefin, and aromatics The carbon numbers of these fractions are in the ranges between C_9 to C_{20} (Naman *et al.*, 2017) (Demshemino S. Innocent *et al.*, 2013) (Romano *et al.*, 2010).

The primary sources of diesel fuels from refinery streams are immediately run middle distillation atmospheric within the range of between 160 to 350 °C and vacuum distillation towers. In contrast, diesel fraction can be mixed with the diesel pond containing heavy cracker naphtha and light Coker oil (Meyers, 2000) (Anjana Srivastava and Ram Prasad, 2000). Moreover, a high substance of sulfur compounds is the most trouble in the usage of diesel oil as a fuel. After combustion, it changed over to sulfur oxides (SOx) and radiated to air as essential contamination. Thus, it led to a large number of diseases for example; emphysema, asthma and bronchitis (Meyers, 2000) (Abdulsalam and Luqman O. Hamasalih, 2013).

The aim of this paper is to evaluate the diesel fuel that has been used in the electric generators of Erbil city in Kurdistan Region-Iraq in two seasons (summer and winter). Therefore, the outcomes of this study are compared with the diesel fuel

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specifications of some countries and Khurmala diesel product.

2.Material and Methods:

2.1Sampling:

Two series of fifty diesel fuel samples in two seasons {winter (W) and summer (S)} were collected directly from the electric generator owner's located different places in Erbil city. To assess the variation between various seasons, the samples were taken and tested at both winter and summer seasons from the same places as shown in **Table 1**. Moreover, the crude oil sample was also taken from Khurmala field, which is located in Erbil city and fractionally distilled to obtain fresh diesel fuel which is distilled at range (170-330 °C). This diesel fuel was taken as a standard for comparison with collected diesel samples.

2.2ASTM Specifications and Equipment

According to the American Society of Testing and Materials (ASTM), the samples were analyzed for specification and evaluation. All tests except cetane number and fractional distillation curve, which provided by petroleum lab from the Ministry of Natual Resource-KRG and green PCB Company-Erbil, were carried out in the Chemistry Department/ College of Sciences/ Salahaddin University, Erbil-Iraq.
Moreover, the total sulfur content of oils was analyzed by utilizing an X-ray sulfur meter, RX-360SH, Japan using (ASTM D4294, 2020). The fractional distillation curve was analyzed using an automated distillation tester, AD-6, Japan according to (ASTM D86, 2020). Moreover, Density determined at 60 °F (15.5 °C) using a pycnometer according to standard method (ASTM D1217-93, 2020), Flashpoint according to (ASTM D92, 2020), Aniline point according to (ASTM D611, 2020), Pour point according to (ASTM D97, 2020). Finally, Cetane number was determined depending on (ASTM D613, 2020) by applying the octane number Zeltex, ZX-101XL, U.S.A.

3 .Results and Discussion:

Today, diesel fuel has become one of the most important petroleum products in the world. Diesel is used worldwide for transportation, manufacturing, power generation, construction and agriculture. All those uses of diesel fuel of cores because of their reliability, efficiency and high power output. Therefore, countries around the world need diesel fuel with higher quality to keep our environment safe and cleaner and to reduce the negative effects of polluted emission of these fuels on our societies. Recently, the demand for diesel fuel over the world is extremely increased, and the amount of polluted emission increased accordingly. Many international organizations interested in improving the environment provide regulations and standards for fuel qualities and periodically make more restriction on applying these regulations and standards (Pirouzfar and Fayyazbakhsh, 2016) .
Generally in our country, especially in Erbil city which was taken as an example, the demand for diesel fuel is in increase especially for the production of electricity beside other sectors. Furthermore, the official refiners are unable to produce enough amount of diesel fuel to cover needs for this sector and thereby different sources appear for marketing through importing diesel fuel from other countries or preparation diesel fuel by blending other petroleum products outside quality controls. According to these considerations, the evaluation of diesel fuel in the electricity sector was more interesting and must take more attention.
For more additional consideration, it was preferred to achieve diesel fuel directly from the fractional distillation of a crude oil sample taken from Khurmala field near Erbil city. The distillation was carried out at a standard range of boiling point for diesel fuel fraction between (170°C-340°C). The same tests were applied for this diesel fuel sample as applied for all diesel samples taken from electricity generation. Generally, for specification and evaluation of diesel fuel, the following tests must be carried out; sulfur amount, density and API gravity, flash point, aniline point, pour point, distillation curve and cetane number. Each of these tests provides indications about the quality of diesel fuel and the overall results used to evaluate and qualifying the diesel fuel.
The evaluation of the diesel fuels samples under the test was carried out by comparison with guidelines and standards of some industrial and

gulf countries beside Iraqi standards which, is shown in **Table 2**. Moreover, the results in **Table 3** illustrate that the specification of the Khurmala diesel sample, which was obtained by fractional distillation of Khurmala crude oil and it was useful for providing an additional guideline for evaluation of diesel samples.

3.1Sulfur Content:

The acid rain containing sulphuric acid is resulted from the reaction of released SO_2 with water . Acid rain and particulate matter production are the major environmental concerns of sulfur pollution. Acid rain has many negative impacts on the environment; including water acidification, soil acidity, and vegetation damage (Mohammed K. Younis and Sherwan Mohammed Simo, 2015).
As shown in **Figure 1**, the sulfur content (wt %) for diesel samples taken in summer season was higher than those taken in the winter season. The sulfur content for the summer sample was ranged between (1.7-3.0 wt %), while the sulfur content of the winter sample was lower and ranged between (1.0-2.5 wt %) with some exceptions. Comparing the sulfur content of diesel fuels in Erbil city with those of worldwide surveyed in 2018 as shown in **Table 2**, it was observed that the sulfur content was out the range of (0.0004 – 0.0007 wt %) in industrial countries, and for gulf countries in the range of (0.02-0.1 wt %) and in Iran is (0.5 wt %), whereas, Iraqi diesel fuel is 0.840 wt %. Moreover, the results demonstrate how much difference was between diesel fuel in Erbil city and those of industrial countries and even gulf countries. The sulfur content of diesel fuel obtained from the fractional distillation of Khurmala crude oil was only (0.5 wt %). As it was seen in **Table 3**, which was acceptable according to Iraqi guideline. Besides, the sulfur content of Khurmala diesel was (2-6) folds lower than those used in the electricity generator sector. In addition to that, as it is shown in Figure 1 and Figure 2 the high sulfur content of diesel fuel samples in Erbil city in both summer and winter season especially summer samples may be attributed to that, the diesel fuels in Erbil city prepared by blending of heavy oil products which already contain a higher level of sulfur compounds.

3.2 Density

Density of diesel fuel provides important an information about the composition of diesel fuels. Low density indicates that diesel fuel has lighter components in its composition. The acceptable value for the diesel fuel density is around (0.83 g/ml) at 15.5 °C. As shown in **Figure 3**, there isn't samples among the overall (50) samples of diesel fuels collected in both winter and summer seasons have a density in the normal density, almost it has a higher density, which ranged between (0.87-0.9) g/ml. Furthermore, Diesel samples in the winter season from (1-7) and (32-46) have densities around (0.84-0.86) g/ml and they are near the normal value as shown in **Figure 3**, while samples from (13-30) have densities between (0.86-0.88) g/ml.
On the other hand, all the diesel fuel samples taken in summer season have higher densities, it was more than (0.88 g/ml) and some samples like (8, 10, 12, 14 and 17) have densities near (0.89 g/ml). These results confirm that the diesel fuels in Erbil city were prepared by blending of different oil products in random ratios without using scientific procedures and standard methods. Accordingly, it was noted that each diesel sample was different than the others in the specification and almost all the samples were obeyed the standard guidelines. However, the density of diesel sample obtained directly from the fractional distillation of Khurmala crude oil was (0.825 g/ml), and it was acceptable according to Iraq, Iran, Kuwait guidelines (**Table 2**, **Table 3,** and **Table 4**).

3.3 Flash Point:

The flashpoint affects the handling and storage of fuel, the low value of flashpoint is an indication of fire hazard. The low flash purpose of diesel oil is that the root of the explanation for several tragic fireplace accidents of diesel storages. (J. Thilagan and R. Gayathri, 2014).
The flashpoint of diesel fuels used in most countries around the world lies between 50 to 60 °C (**Table 5**). While the flashpoint of some diesel fuel samples, which have been used in Erbil, was below room temperature (below 25 °C) and the others were between (30 – 40) °C (**Figure 4**). The flashpoint of diesel samples was lower than those listed in and this may cause difference

risks during storage and transportation, also may be evaporated to the atmosphere and cause additional air pollution.It was observed that the flashpoint of summer samples was generally higher than those of winter samples, as it was illustrated in **Figure 4**.

3.4 Aniline Point:

The Aniline point is the lowest temperature at which the same volume of aniline and oil is completely miscible (clear). The aniline point (AP) is roughly correlated with the amount and type of aromatic hydrocarbons in the oil sample. The low AP is an indication of higher aromatics content and vice versa. Diesel oil with AP below 120 ° F (49 °C) is likely to be hazardous to use. The lower the Aniline point, the higher the solvency or reactivity of the oil, which in turn gives an aromatic indication of the oil. For example, for aromatic oil with a 75% aromatic content, the aniline point would be between 32 °C and 49 °C. For naphthenic form with a 40% aromatic composition, it would be between 66 °C and 77 °C, and for paraffin oil with a 15% aromatic content, it would be between 93 °C and 126 °C. (Rajesh Kanna *et al.*, 2017).
With respect to these values, and according to the determined aniline point of diesel samples, which were utilized in this study, as shown in **Figure 5**, the most of the diesel samples contain less than 40% aromatic and have naphthenic character. An exception was observed for samples (5,16 and 48), which have aniline point near 90C^{o,} that is the indication for lower aromatic content (15-204 wt %) and have paraffinic characters.

3.5 Pour point:

Pour point provides information about waxy materials in the diesel fuel, which refers to the presence of long-chain aliphatic hydrocarbons. Normally, by increasing the weight ratios of these long-chain hydrocarbons the pour point accordingly increases. At low temperature especially at cold weather, the waxes will separate from the diesel and then coagulate forming bulky layer cause difference problem to the internal combustion engines during working (Saeedi Dehaghani and Rahimi, 2019).

As it was explained in **Table 2**, the pour point of diesel in industrial countries which already have cold weather ranged between (-23 °C to -33 °C), while in Gulf countries the pour point arises to the range between (-3 °C to -6 °C). Even according to Iraqi guideline the pour point is (-9 °C) because these countries have relatively hot weather and the wax under these conditions will not separates from the diesel fuel. The results in **Figure 6** shows a wide range of fluctuation ranged between (+9 °C to -15 °C) in winter diesel samples and (+10 °C to +5 °C) in summer diesel samples. Moreover, the samples (32, 33, 35) in both winter and summer seasons have fixed and acceptable pour point, which was -15 °C, whereas, it was about -9 °C for sample 34 in both seasons. Besides, the rest samples have pour point above 0.0 °C either in both seasons or summer season and all were not acceptable according to even to Iraqi guideline (see **Table 2**).
On the other hand, the pour point of diesel, which obtained from the fractional distillation of Khurmala crude oil was (-15 °C) which is acceptable according to Iraqi even to worldwide diesel fuel guideline. As it was mentioned earlier the an acceptable pour point of commercial diesel fuel in Erbil city referred to random procedures, which have used for the blending process between different types of diesel and other oil products.

3.6 Distillation Curve:

Distillation curves gives knowledge that enables quality to be associated with the efficiency of the engine. The temperature of 10% of the recovered volatilized gas fraction represents the case of vaporization, while the temperature of 90% of this fraction suggests the presence of high molecular weight compounds that will be difficult to vaporize entirely, preferring the emission of particular matter (PM) and unburned hydrocarbons (HCs) (Cataluña and da Silva, 2012).
Set of seven samples (6,17, 23, 32, 34, 35, and 49) in both seasons were chosen from both winter and summer seasons to evaluate their distillation curves as are illustrated in **Figure 7** and **Figure 8**. In this set, there was no sample completely field in all fractional ranges with standard distillation curves, but a few samples like 34S and 35W have distillation curves similar to the standard

distillation curves (see **Table 2**). Other samples like 32S, 32W, 35S and 35W have similar IBP, 10%, and 50%distillation temperature, but their 90% and FBP appear at lower temperature and this means that these samples contain higher levels of light petroleum fractions.
Moreover, the distillation curve of Khurmala diesel sample as it was explained in **Table 3** was in similar temperature ranges as for standard distillation curve provided as guideline survey 2018 (**Table 2**).

3.7 Cetane Number:

Cetane number is an associate degree empirical parameter related to associate degree ignition delay time of diesel fuels. Low CN means longer lag time causes an increase in the emission of unburned hydrocarbons and particulate matter Cetanus number (C.N.) also affects direct fuel consumption, with a propensity to decrease fuel consumption as CN rises due to higher combustion cycle temperatures and improves engine thermal performance. (Cataluña and da Silva, 2012).
A set of samples, which were included (6, 16, 17, 32, 33, 34, 35 and 49) for both winter and summer seasons were taken to determine their cetane number as are presented in **Figure 9**. The cetane number of the samples was between (44.3 to 47.8), while the acceptable value of cetane number is above 50 as mentioned in **Table 2**. The cetane number of Khurmala diesel sample was (51) as in **Table 3**.

4 Conclusion:

1- The sulfur content of diesel samples in the winter season was relatively lower than those of the summer season. But the sulfur content of diesel samples of both winter and summer season was very high with respect to worldwide guidelines.
2- The density of the summer season samples was relatively higher than those of the winter samples and all the samples have higher density according to guidelines.
3- Flash point of most diesel samples was below room temperature and others were between (30-40) °C.
4- From aniline point, it was concluded that most of the diesel samples were naphthenic character.
5- Pour point of some samples was above zero temperature and only 25% of the samples have pour point between (-9 to -15) °C.
6- The cetane number of all the samples was lower than 50 and it was around 40.
7- The distillation curve of selected samples provide an indication that the sample has a low temperature of IBP, 10% distillation and normal range temperature of 50%, 90% and FBP.
7- The diesel sample obtained from the fractional distillation of Khurmala crude oil gave acceptable results according to Iraqi guideline.
Therefore, the overall conclusion observed from the evaluation of diesel samples, which have been used in electricity generator section has low quality according to guidelines because the diesel fuel for this sector was prepared by blending of different petroleum product not by professional persons using uncorrected procedures without quality control. An accepting was observed from the specification of diesel fuel used by Teammart group for their electricity generators. This group brought a large quality of diesel fuel produced directly from Kar, Hawler and Kirkuk refineries or from Iran. Besides, the diesel obtained from them directly fractional distillation of Khurmala crude oil also has acceptable quality according to Iraqi guideline.

Table 1: sample code and locations:

Sample code	Location	Place
1D	36.164028, 44.028283	Andaziaran – Wafai park
2D	36.191328, 44.012026	Swrchyan street
3D	36.162664, 44.024823	Andaziaran
4D	36.151111,44.047515	Galawezh

5D	36.181564,44.029233	Mamostaian 1
6D	36.157939, 44.017528	Mantkawa- near Chihan Bank
7D	36.215332, 44.023044	Ulama – Shix Najmadin Mosque
8D	36.209765, 44.019949	Near Shorsh Stadium
9D	36.184680, 44.037141	Near Langa bazar
10D	36.189443,44.036679	40 meter street –near Top Med Laboratory
11D	36.153923,44.031306	99 Zanko – near Dli Kurdistan School
12D	36.169620 , 43.989301	Gulan street – Muhammad Bajalan Hospital
13D	36.169523,44.030675	Badawa – near Perezhn Mosque
14D	36.170891,44.025740	Near Mufty
15D	36.176431,44.012574	40 meter street – near Hawler School for Girl
16D	36.168860,43.985578	Kurdistan street- near Sharawany 6
17D	36.163682,44.067321	Near Haji Ali Shakr Mosque
18D	36.149412,44.032381	Zanko village
19D	36.168097,44.995290	Kuran
20D	36.173000,43.984301	Kurdistan street – near Safa & Marwa Mosque
21D	36.192702,44.065882	Hiran city
22D	36.176281,43.970729	Nawroz street – near Shahed Abdullqadr Mosque
23D	36.124181, 44.055163	Daratw – near Mala Nwri mosque
24D	36.156059,44.063909	Farmanbaran – near Galawezh School
25D	36.148973,44.060433	Farmanbaran – near Shahed & Anfalkrawakan Mosque
26D	36.174005,43.980299	Nawroz
27D	36.158433,44.059296	Farmanbaran – near Bnasllawa street
28D	36.158086,44.071827	Farmanbaran – near Brwadaran Mosque
29D	36.151833, 44.023266	92\Mhabad – near Shanga beri school
30D	36.156580, 44.022804	92\Mhabad – near Haji Yahia Mosque
31D	36.140733, 44.033864	Mamostayan 2 – near Frdaws Mosque
32D	------------------------	Kar diesel for Teammart Group
33D	------------------------	Hawler diesel for Teammart Group
34D	------------------------	Iran diesel for Teammart Group

35D	------------------------	Kirkuk diesel for Teammart Group
36D	36.168346, 44.019387	Runaky – near School Activity
37D	36.170671, 44.026020	Mufty – Flower nursery Chihan
38D	36.149347,44.042978	Mamostayan
39D	36.172258,44.014766	Komare – Near Haji Salam Mosque
40D	36.146491,44.020478	Mhabad – near 92-Apartments
41D	36.163911,43.991075	Opposite Walee Dewana School
42D	36.156519,44.043095	Sharawani
43D	36.170758,44.032404	Mufty
44D	36.146842,44.056399	Farmanbaran – 6000
45D	36.158382,44.026559	92 Mhabad – near Ahmadi khane High School
46D	36.179690,44.025753	Malafande street – near Shex Maarwf Graveyard
47D	36.159136, 44.031441	Zanko – near Hamid Sian Mosque
48D	36.166696, 44.022254	Runaky – near Runaky High School
49D	36.169970, 44.022458	Runaky – near Sharawany 5
50D	36.173001, 44.025602	Mufty – near Eskan Police Station

Table 2: Worldwide Diesel Fuel Quality Survey 2018 (Infineum International Limited, 2018).

Country	Sulfur Content (Wt%)	Density 15.5 °C g/ml	Cetane Number	Pour point	Distillation IBP °C	%10	%20	%50	%90	%95	FBP
Germany	0.0007	0.835	54	-30	172	207	224	273	336	352	361
France	0.0007	0.836	52	-26	163	196	215	269	337	356	361
UK	0.0007	0.836	52	-24	170	205	223	268	333	354	361
Japan	0.0007	0.823	50	-28	161	193	210	254	319	335	351
USA-W	0.0004	0.828	53	-23	172	211	223	258	321	337	350
Russia	0.0007	0.824	50	-33	162	196	211	251	314	332	344
Kuwait	0.1029	0.845	51	-6	193	231	249	290	350	368	378
Qatar	0.0221	0.831	58	-6	204	245	256	282	343	368	375
Turkey	0.0004	0.830	57	-24	165	209	233	281	344	363	368

Saudi Arabia	0.0381	0.835	53	-13	187	219	232	271	338	350	367
Iran	0.5	0.847	N/A	-3	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iraq	1.0000	0.840	53	-9	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Table 3: the test results for Khurmale diesel fuel.

Test		Result
Density at 15.5 °C (g/ml)		0.825
Sulfur content (wt %)		0.5140
Flash point (°C)		43
Pour point (°C)		Below -15
Aniline point (°C)		62
Cetane number		51
Distillation curve	Initial B.P.	170 °C
	10%	192 °C
	50%	268 °C
	90%	324 °C
	95%	338 °C
	Final B.P.	346 °C

Table 4: Classification of sulfur content (wt.-) from lower to higher diesel samples

Sample Group	Sample number	Sulfur content (wt %)
Group 1	6 34 35 32 17	(0.0-1.0) wt %
Group 2	12 10 8 45 44 39 41 46 38 43 40 37 4 3 2 1 33 14 23 7 9 5 25 22 29 24 21 26	(1.0-2.0) wt %
Group 3	42 36 47 11 48 28 13 50 19 27 30 31 15 20 18 49 16	(2.0-3.0) wt %

Table 5: Standard Flash point values of some country (J. Thilagan and R. Gayathri, 2014):

Country	Australia	China	Germany	Japan	Malaysia	Norway	U.K.	U.S.A.
Diesel flash point (°C)	61	66	56	50	60	60	56	54

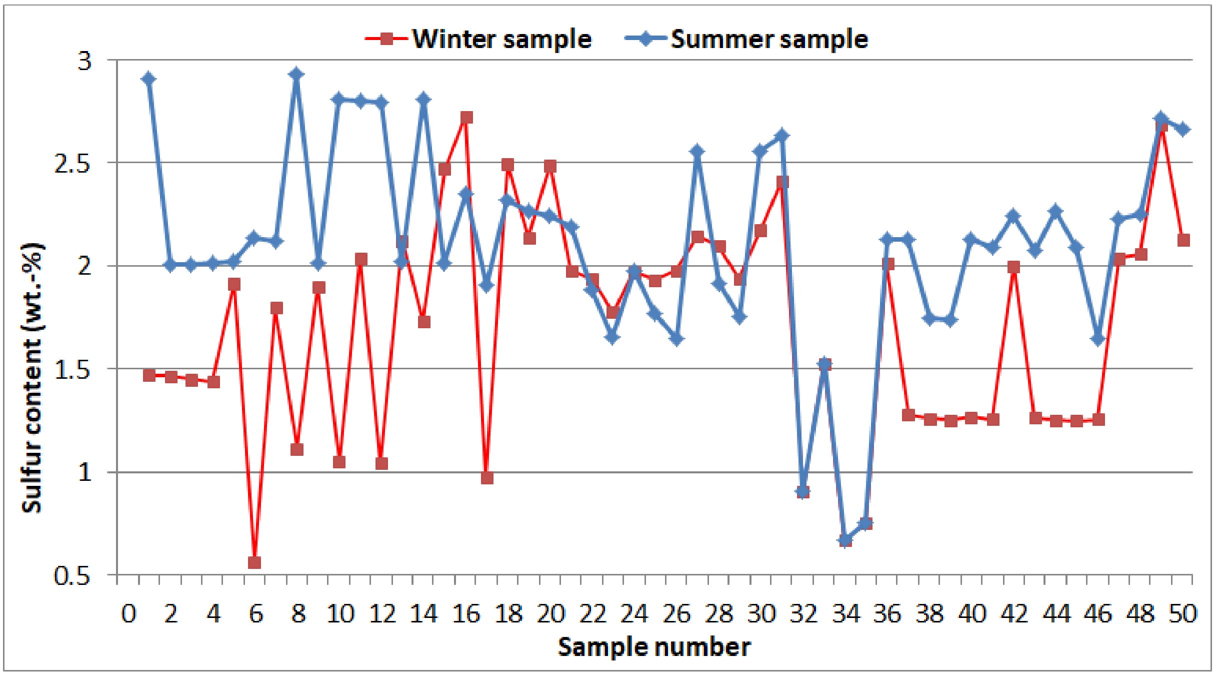

Figure 1: sulfur content in diesel sample

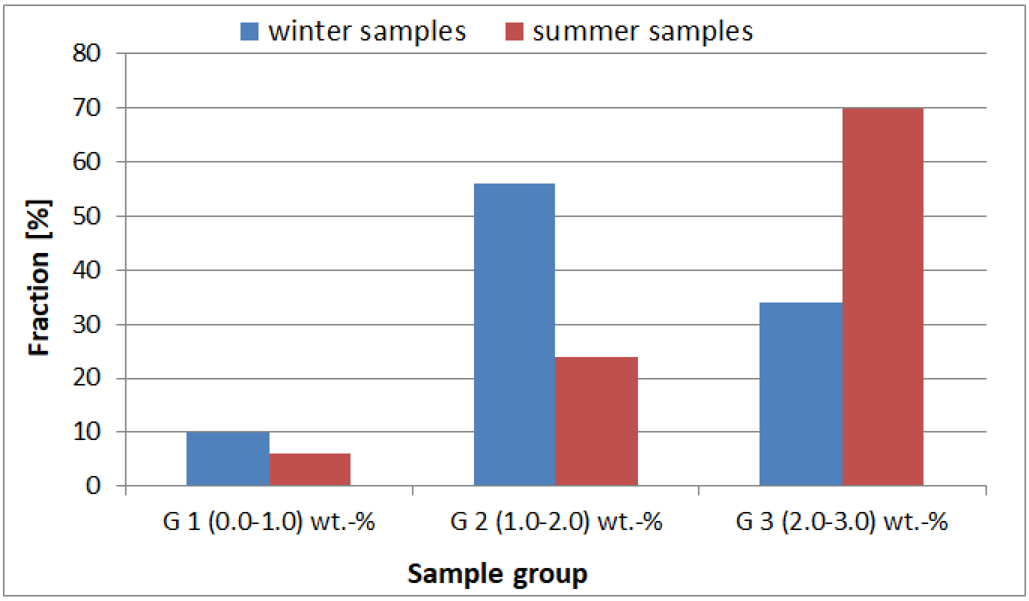

Figure 2: Classification of sulfur content (wt.-) of diesel samples

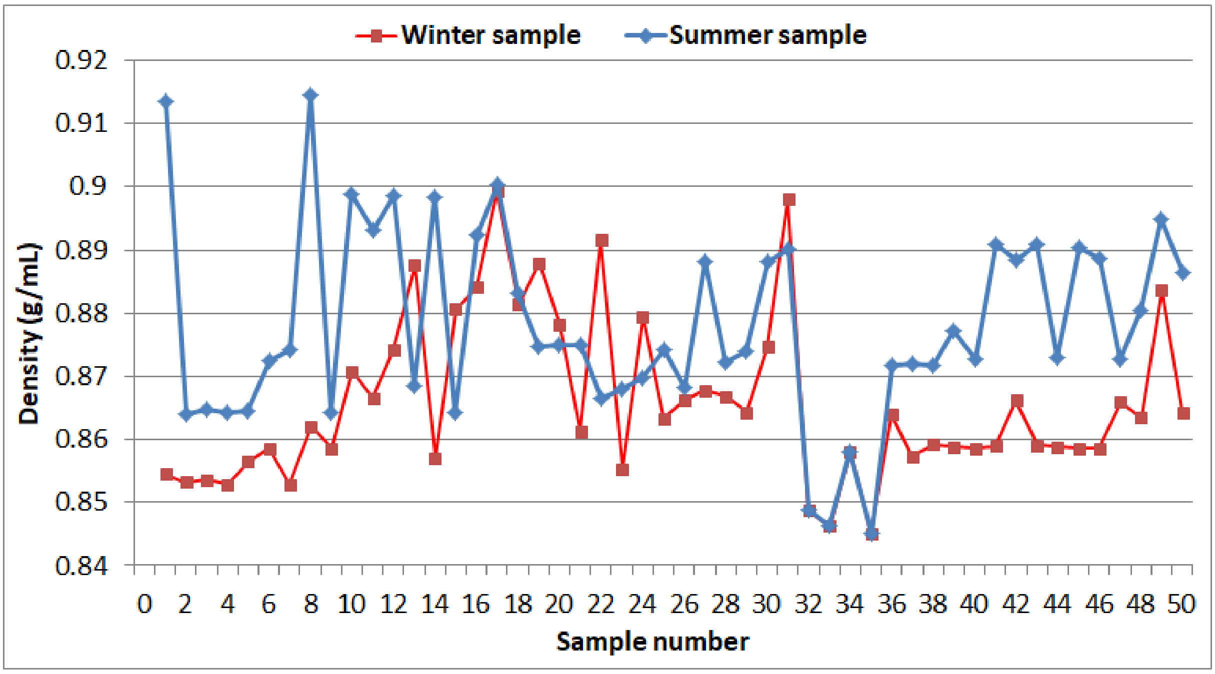

Figure 3: Density of diesel sample

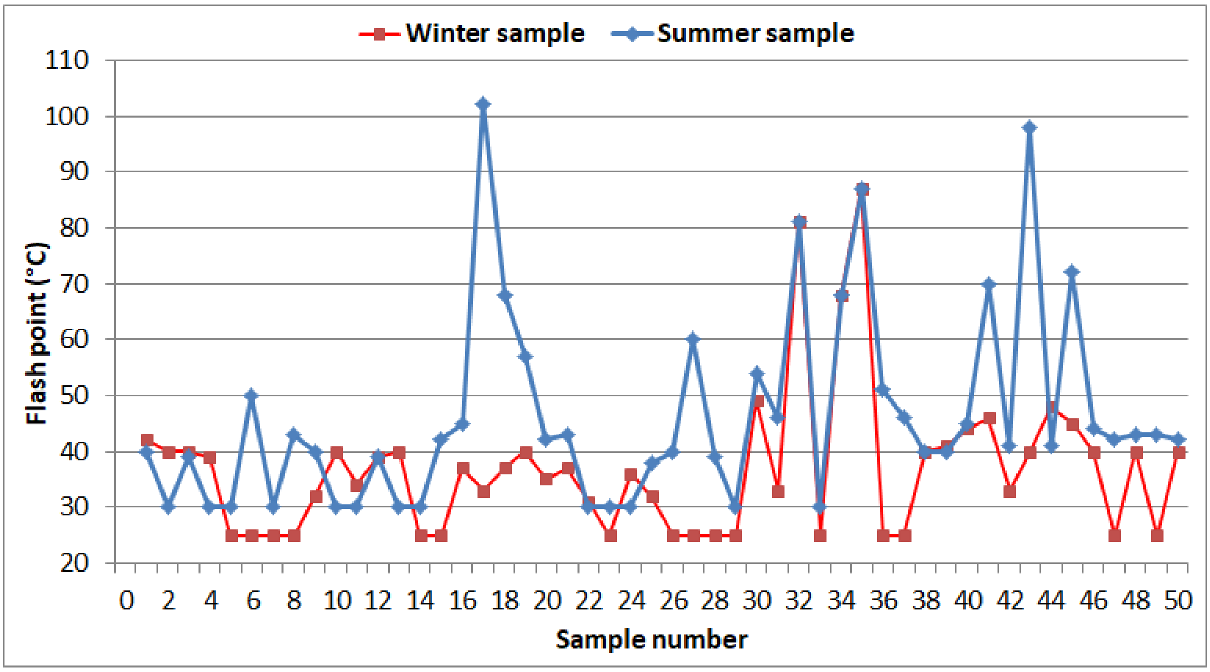

Figure 4: Flashpoint of diesel samples

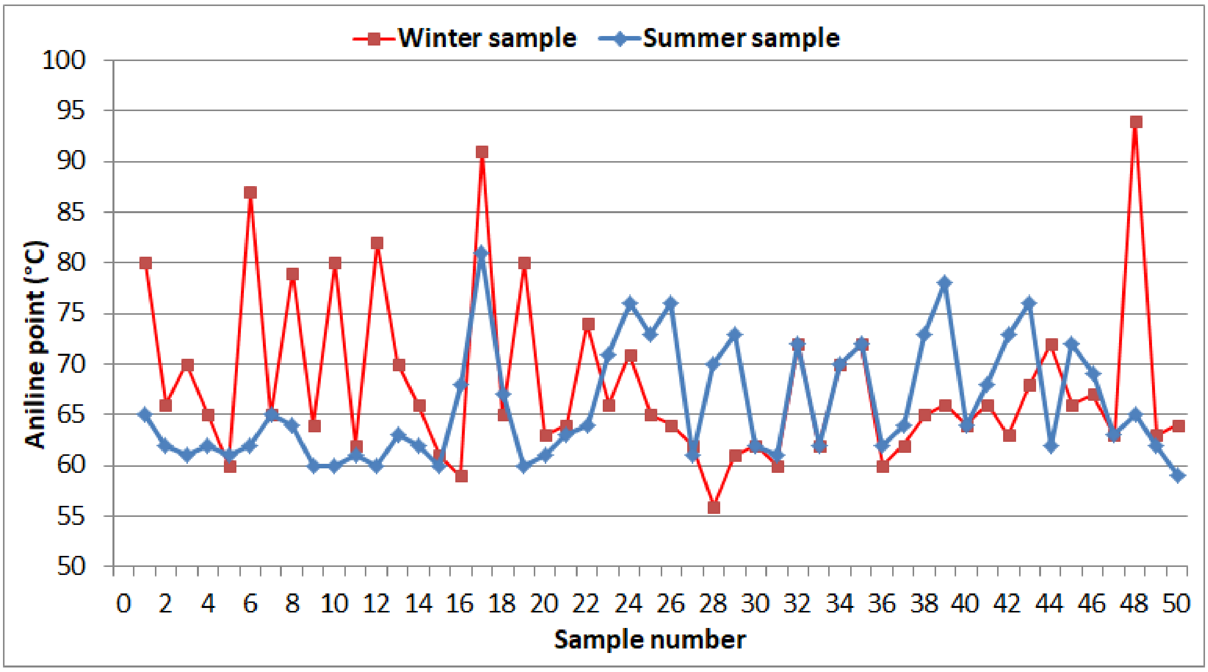

Figure 5: Aniline point of diesel samples

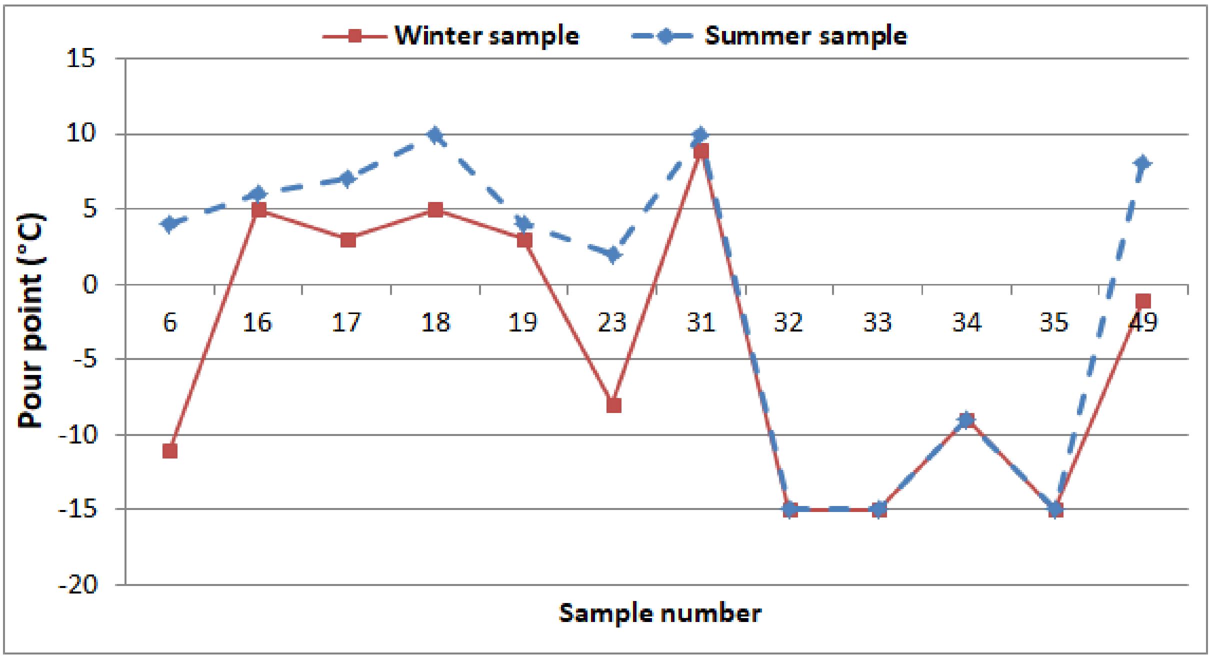

Figure 6: Pour point of diesel samples

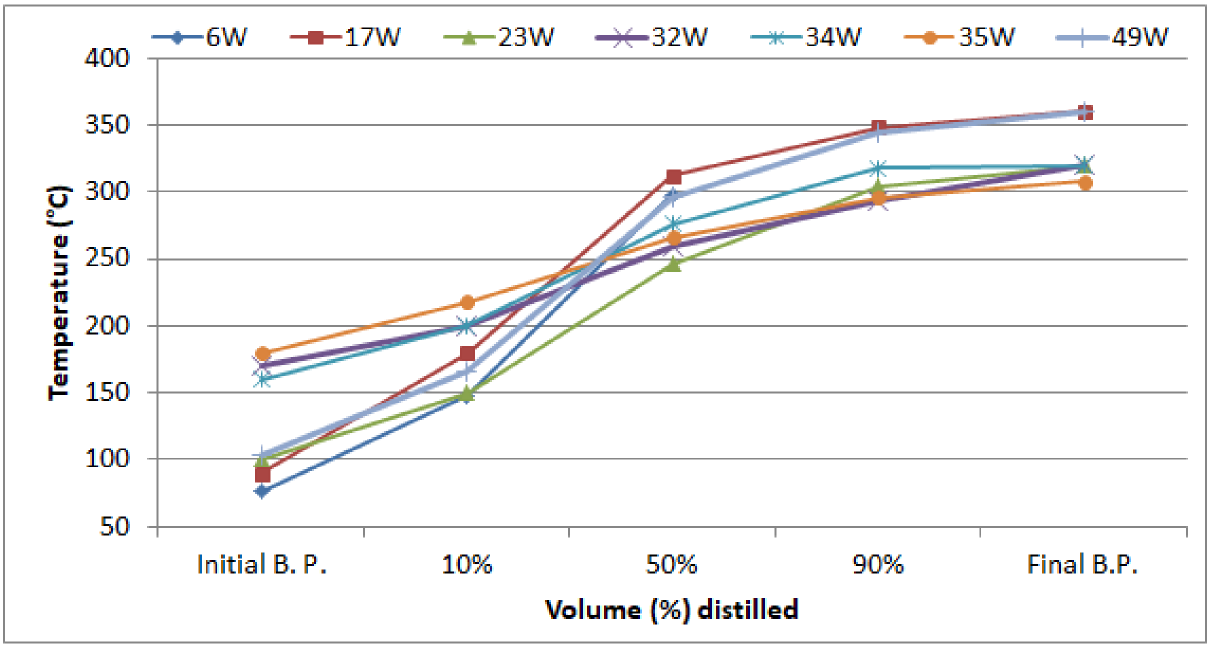

Figure 7: Distillation curve for diesel samples in the winter season.

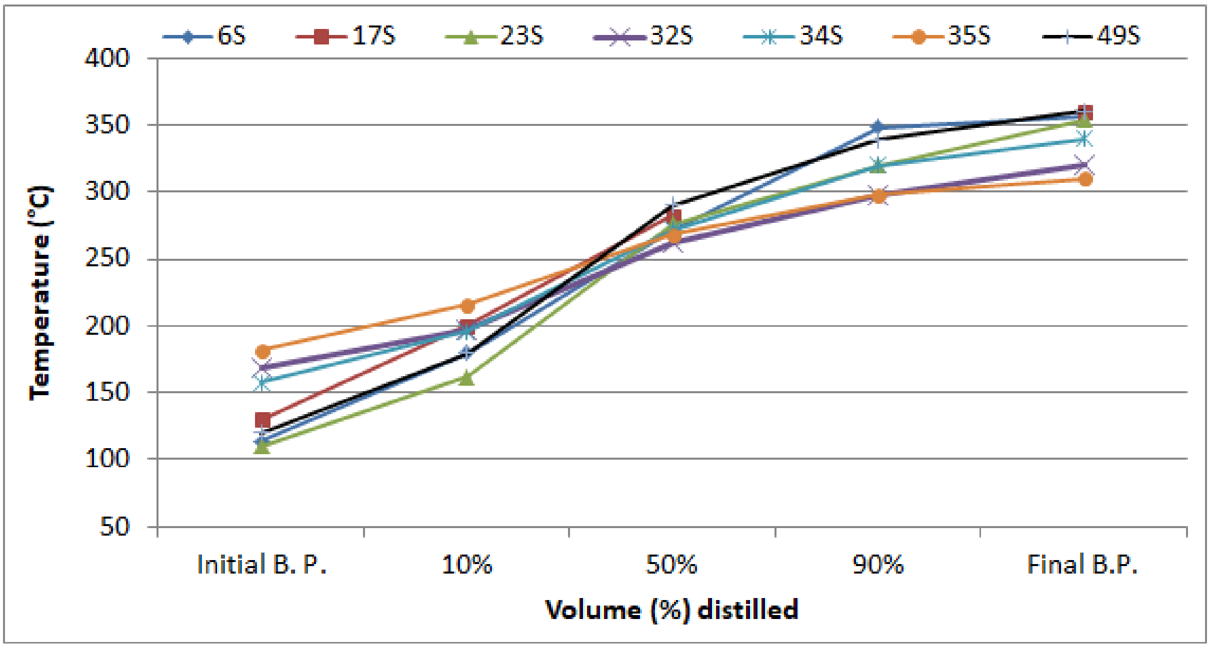

Figure 8: Distillation curve for diesel samples in the summer season.

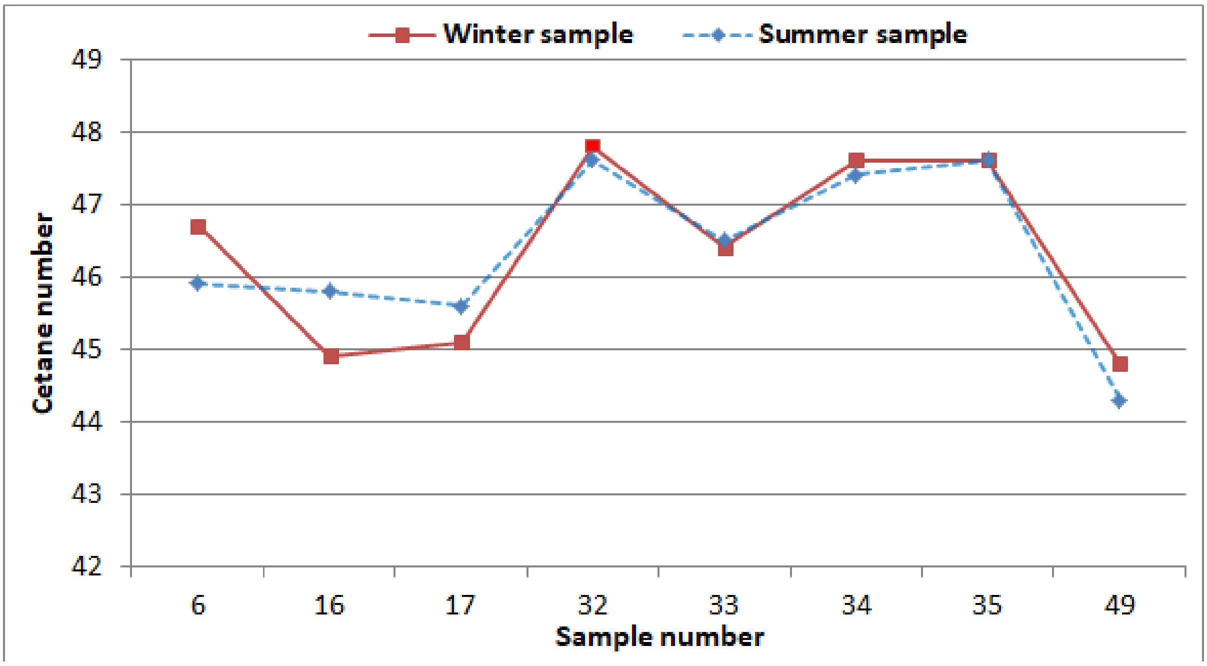

Figure 9: Cetane number of diesel samples

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