REGENERATION OF SPENT TRANSFORMER OIL

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ABSTRACT
The regeneration of spent transformer oil taken from Al-Dora power station was studied. The regeneration process includes settling, filtration, thermo vacuum evaporation, and clay treatment. The settling was done by gravity to remove the mechanical particles. The filtration was done by filter paper [whatman quality1 and 18.5 cm diameter]. Thermo vacuum evaporation at 175˚C and 241 mm Hg was used for removing the dissolved water and light petroleum impurities. The clay treatment was used for final improvement of transformer oil properties. Iraqi clay, Algerian clay and zeolite (A) were used and the results were compared. It was studied the effect of clay to oil ratio and the mixing time on the water content, break down voltage and the acidity. It was considered that the best operation conditions are clay to oil ratio 2/100, and time 5 min. In these conditions the oil has water content 32 ppm, break down voltage 55 kV and acidity 0.028 mg KOH/g oil. It was found that Algerian clay gives better improvement than zeolite and Iraqi clay using the same operating conditions. Langmuir, Freundlich, and the combination of them adsorption isotherms were studied in this investigation and It was found that Freundlich adsorption isotherm well represented the adsorption of water on clay comparing with others isotherms.

الخلاصة
تم دراسة عملية إعادة استخدام زيت المحولات المستهلك والذي تم أخذه من محطة كهرباء الدورة. إن عملية إعادة الاستخدام تتضمن ترسيب, تصفية, تبخير بواسطة الحرارة والفراغ, ومعاملة بواسطة الأطيان. تم الترسيب بواسطة الجاذبية الأرضية لإزالة العوالق الميكانيكية. عملية التصفية بواسطة ورق تصفية (واتمان نوعية 1, قطر 18.5سم) استخدمت لإزالة الشوائب التي لا يمكن إزالتها بالترسيب. التبخير الحراري الفراغي في 175˚م و 241 مليمتر زئبق استخدمت لإزالة الماء الذائب و الملوثات النفطية الخفيفة المسببة زيادة الحامضية وقلة العزل للزيت. المعالجة الطينية إستعملتْ للتحسينِ النهائي لخواص زيت المحوّلاتِ.الطين العراقي, الطين الجزائري, والزيولايت نوع (أ) استخدموا للمعاملة النهائية وتم مقارنة النتائج. تم دراسة تاثير نسبة الطين الى الزيت ووقت المزج على خواص المحتوى المائي والعازلية والحامضية. قَدْ يَعتبرُ إن أفضل شروطِ العمليةِ إن نسبة الطين إلى الزيت هي 2\100، وبُوقْت 5 دقيقة. في هذه الشروط يكون للزيت محتوى مائي 32 جزء بالمليون ، والعازلية 55 ك ف, وحموضة 0.028 ملغم KOH \غم زيت. لقد وجد ان الطين الجزائري افضل من الزيولايت والطين العراقي باستخدام نفس الظروف التشغيلية. صيغ الامتزاز لونكماير, فريندلج, وصيغة اتحادهما قد دُرِسَت في هذا البحث وقد وجد ان صيغة فريندلج للامتزاز تصف عملية امتزاز الماء على الطين أفضل من الصيغ الأخرى.

KEY WORDS: Spent Lubricating Oil, Transformer Oil, Spent Mineral Oil, Regeneration, Insulating Oil, Clay Treatment,

INTRODUCTION

Transformer oil is one of the lubricating oils and it has several main functions in a transformer; like cooling and electrical insulation. Besides those there are several secondary functions and properties expected from transformer oil [1]. Impurities in transformer oil are unavoidable, the primary impurities are moisture and dissolved gases and usually accompanied by solids [2]. Used lubricating and industrial oils present a serious pollution problem and it was estimated that less than 45% of available waste oil was collected worldwide in 1995 and classified according to current world regulations as hazardous waste due to the effects that they can have both on health and the environment [3, 4]. A large range of used (waste) oils can be recycled and recovered [5]. The change in the composition of transformer oil in operation is related to the chemical processes that occur in the dielectric medium under the action of temperature and high voltage. This leads to the oxidation and decomposition of chemical compounds that enter into the composition of the oil and to the appearance in it of new gases (CO, CO_2, and volatile hydrocarbons), liquids (aldehydes, ketones, alcohols, acids, ethers, resins, and water), and solids (asphaltenes and carbenes) chemical products [6]. Water can be present in oil in a dissolved form, as tiny droplets mixed with the oil (emulsion), and in a free state at the bottom of the container holding the oil [7]. Regeneration is the procedure followed if oil purification is insufficient to return the oil to an acceptable condition and usually done by specialist companies [2, 8]. This work deals with decreasing the mechanical impurities, water content, and acidity and increasing the break down voltage of spent transformer oil, by settling, filtration, thermo vacuum evaporation, and clays treatment.

MATERIALS AND METHODS

A-Materials

-Spent Transformer Oil: The raw material was the spent oil of type (Diala-D), Germany origin. This oil was used in Al-Dora power station for about 15 years in transformer to change the voltage from 6600 V to 380 V. The spent transformer oil has the properties illustrated in table 1.

-Adsorbents: The Iraqi clay manufactured by the State Company for Geological Survey and Mining, Algerian clay (from Al- Dora refinery) and zeolite type (A) were used for final treatment of spent transformer oil. Table 2 shows the properties of these clays, while figure 1 shows the X-ray analysis for the zeolite.

Table 1 Properties of spent transformer oil

The property	The value
Water content, ppm	50
Break down voltage, kV	30
Acidity, mg KOH/g oil	0.1122
Specific gravity at 60/60˚F	0.87167

Table 2 Properties of clays

The property	The value (Iraqi clay)	The value (Algerian clay)
Particle size, micro meter	Greater than 85	Greater than 85
Ignition loss at 100˚C, wt %	8	6
SiO_2, wt %	48	78
Al_2O_3, wt %	34	12
Fe_2O_3, wt %	4	2
MgO, wt %	2	1
CaO, wt %	4	1

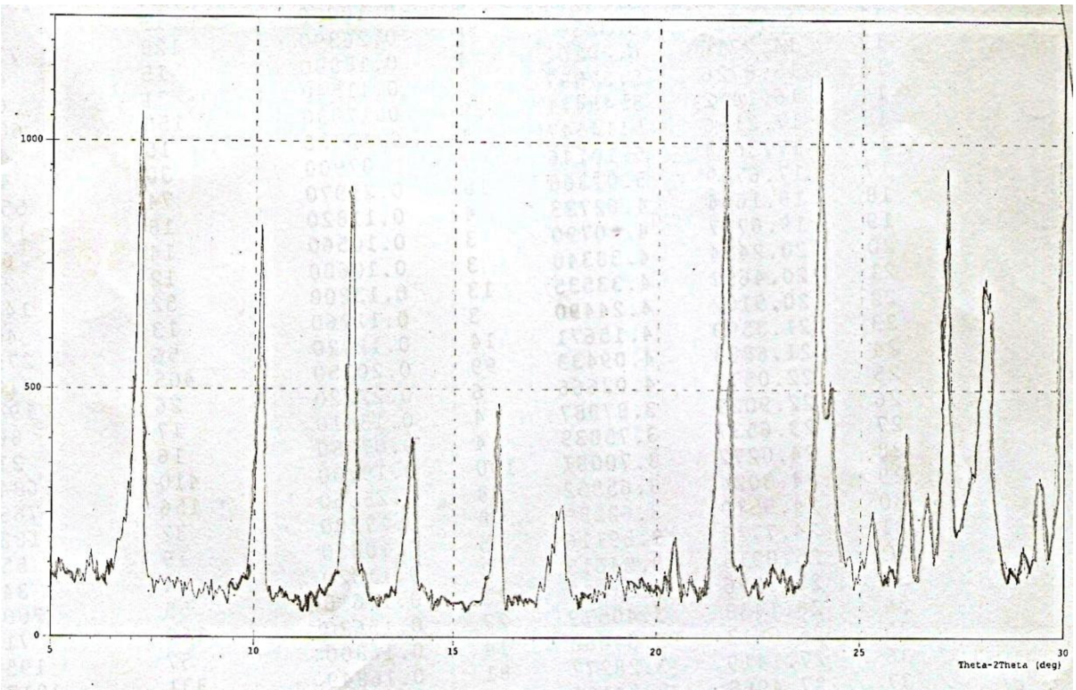

Figure 1 X-ray analysis for the zeolite

B-Methods

- Settling: The mechanical particles would be found as impurities, the spent oil was settled for a week in a reservoir. Settling was done by gravity because the mechanical particles are heavier than oil.

- Filtration: The fine particles could not be settled by gravity so the filtration is very important step because it removes any remaining particles. The filter papers (WHATMAN type and quality 1, 18.5 cm diameter) were used for filtration. Figure 2 shows a photo for batch filtration unit. To calculate the quantity of the remaining particles on the filter paper, the paper washed by gasoline. The gasoline dissolved the oil from the filtration paper and then the filtration paper put in oven at 100 ˚C for 3 hours.

Figure 2 Photo of Batch Filtration Unit

- Thermo Vacuum Evaporation: This step took place at a temperature of 175˚C and a pressure of 241 mm Hg in a laboratory evaporation unit shown in figure 3. During the thermo vacuum evaporation light petroleum impurities was separated. The percentage of light petroleum impurities on the settled and filtered oil was 10.37 %.

Figure 3 Photo of Thermo Vacuum Evaporation Unit

-Adsorbents treatment: This is the final step of the treatment and used for final decreasing of water content in the oil. In this study the Algerian clay to oil ratio range was 1/100 to 10/100 while contact time varied from 5 to 30 min. All tests were taken place at 80˚C. Iraqi clay was tested at ratio 2/100 at different contact times, while zeolite was tested at ratio 1/100 and different contact times (5 – 30 min.). 523 g of the oil produced from thermo vacuum evaporation was injected into flask and heated up to 80 ˚C. Then, the specified quantity of clay or zeolite was added during mixing for specific contact time. Figure 4 shows the unit of clay and zeolite treatment. After specific contact time the mixture of the oil and adsorbent filtered by filtration paper [WHATMAN quality 1, having a diameter 18.5 cm] using the filtration unit shown in figure 2.

Figure 4 Photo of Adsorbent Treatment Unit

The clay that produced from the adsorption process was washed by a gasoline to dissolve the oil deposited on the clay and on filter paper for the adsorbate estimation. The washed clay and filtration paper were put in the oven at 100˚C to evaporate the gasoline from them.

RESULTS AND DISCUSSION

-The Settling and Filtration Steps: The settling of spent transformer oil for one week resulted in 0.01% of mechanical impurities removal, while the filtration of the oil after settling removed 0.23 % of impurities. This means that the total percentage of mechanical impurities removed by settling and filtration is 0.24 %.

-The Thermo Vacuum Evaporation Step: The total light petroleum impurities removed during the thermo vacuum evaporation step was 10.37 % based on settled and filtered oil. This means that the percentage of oil produced from thermo vacuum evaporation was 89.61 % based on the original raw material. Table 3 shows the properties of the oil before and after thermo vacuum evaporation.

Table 3 The Basic Properties of Spent Transformer Oil Before and After Thermo Vacuum Evaporation

Property	Before thermo vacuum evaporation	After thermo vacuum evaporation
Water content, ppm	50	42
Break down voltage, kV	30	57
Acidity, mg KOH/g oil	0.112	0.028

-The Results of Clays and Zeolite Treatments: For reducing the water content down to acceptable value, clay treatment was used. The Iraqi clay was used in 2/100 clay to oil ratio and duration time (5 - 30 min) at 80˚C. The water content of oil decreased from 41 ppm to 39 ppm, this value is not acceptable by standard properties. So, the Algerian clay was used in this step. The operating conditions are clay to oil ratio (1/100 -10/100) and duration time (5 - 30 minutes) and temperature 80˚C. Zeolite was also used using 1/100 zeolite to oil ratio, duration time (5 -30 minutes) and temperature 80˚C. The basic properties of the transformer oil after Iraqi clay, zeolite and Algerian clay treatments were presented in tables 4, 5 and 6, respectively.

Table 4 Water content of transformer oil after Iraqi clay treatment for 2/100 clay to oil ratio

No.	Time, min	Water content, ppm
1	5	41
2	15	39
3	30	39

Table 5 Water Content of transformer oil after zeolite treatment for 1/100 zeolite to oil ratio

No.	Time, min	Water content, ppm
1	5	40
2	15	39
3	30	38

Table 6 Basic properties of transformer oil after Algiers clay treatment

No.	Clay to Oil Ratio	Time, min	Water content, ppm	B.D.V., kV
1	1/100	5	36	-
2		10	-	-
3		15	35.4	-
4		20	-	-
5		30	34	-
6	2/100	5	32	55
7		10	-	54
8		15	31	46
9		20	-	44.5
10		30	30	36.5
11	5/100	5	26	52.5
12		10	-	47
13		15	23	45
14		20	-	42
15		30	22	35
16	7/100	5	25	51.5
17		10	-	46
18		15	23	40
19		20	-	35
20		30	21	34
21	10/100	5	25	51
22		10	-	45
23		15	22	38
24		20	-	34
25		30	20	32

- Effect of Algerian Clay to Oil Ratio on Water Content: Figure 5 shows the effect of Algerian clay to oil ratio on the water content at different duration time. The increase of clay to oil ratio decreased the water content in the oil for the same contacting time because of the increasing of contact surface between the oil and the clay.

- Effect of Mixing Time on Water Content: Figures 4-6 – 4-8 show the effect of mixing time on the water content at different adsorbent to oil ratio. Whenever the contact time increases, the water content decreases for the same adsorbent quantity. Figure 6 shows a comparison between Algerian clay and zeolite treatments at different duration time. This figure shows that the Algerian clay is better than the zeolite in removing dissolved water. Figure 7 shows a comparison between the Iraqi clay and the Algerian clay. This figure illustrates that Algerian clay is better than the Iraqi clay. This may be because of the low percentage of silica in the Iraqi clay than the Algerian clay and the high percentage of Fe_2O_3, MgO, and CaO in the Iraqi clay as shown in table 2. The silica had a large adsorption area and it was a good adsorbent for the water

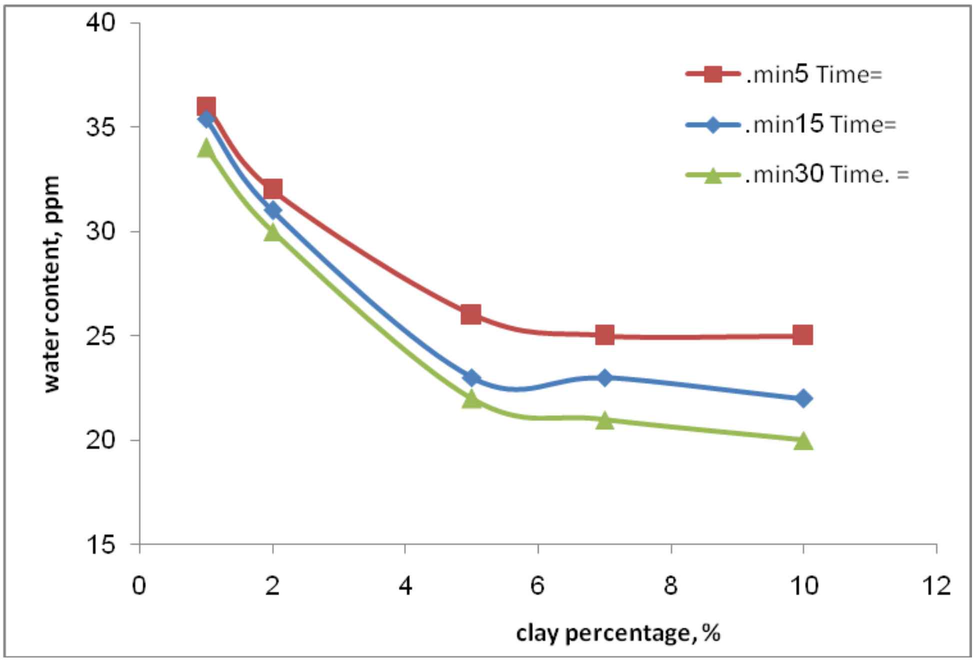

Figure 5 Effect of Algerian clay to oil ratio on the water content at different mixing times

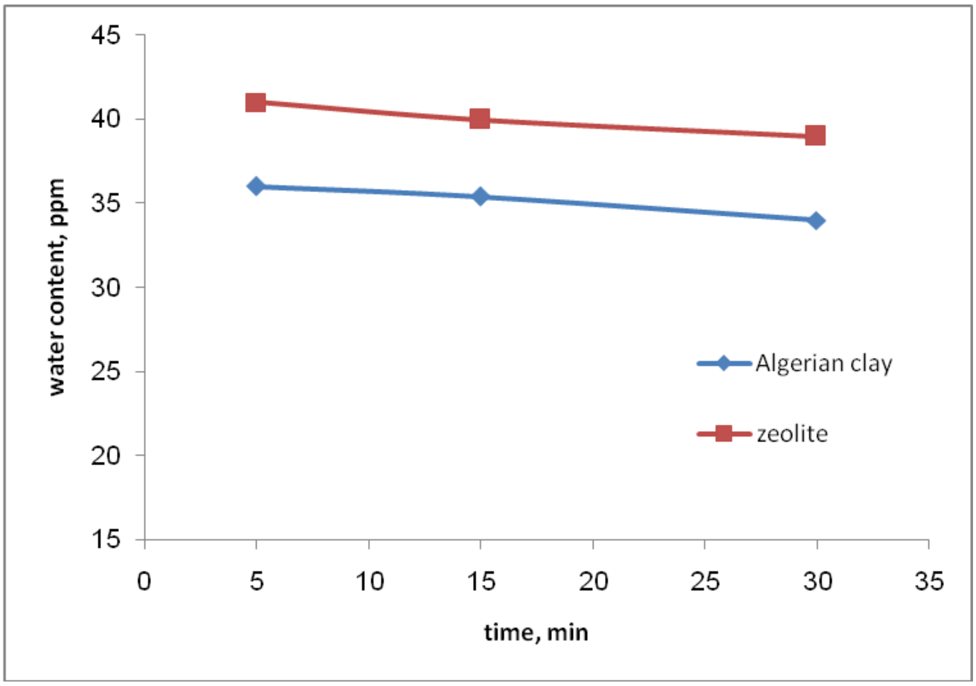

Figure 6 Effect of mixing time on the water content at 1/100 Algerian clay and zeolite to oil ratio

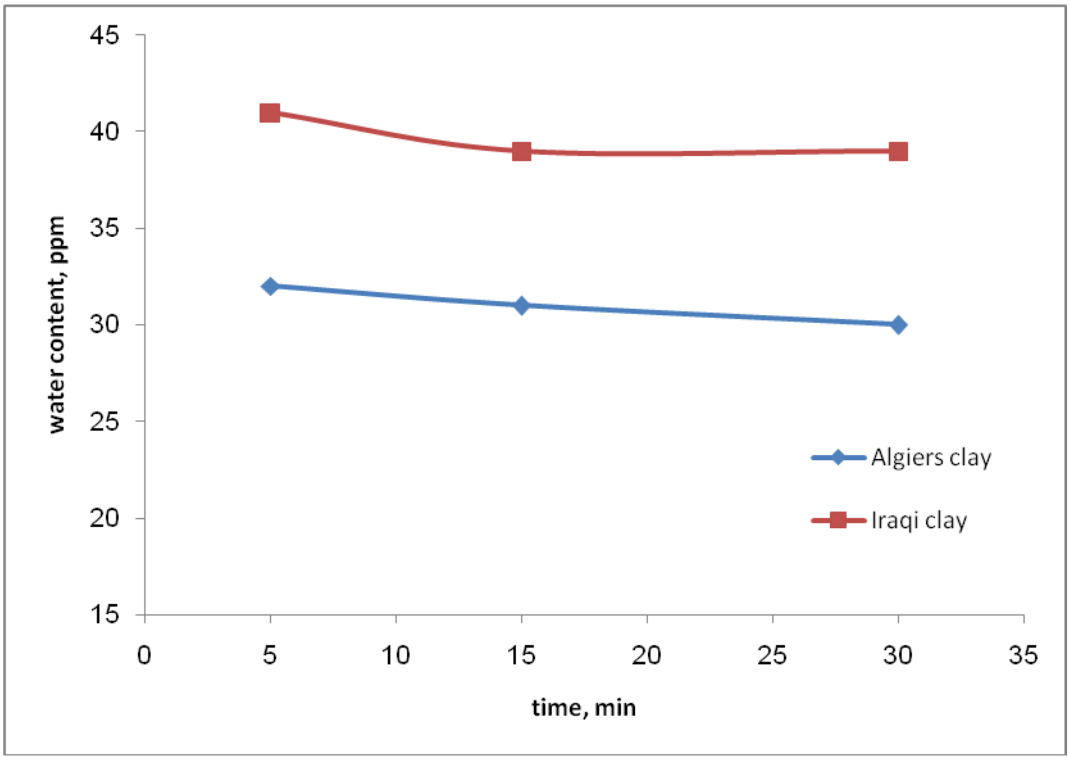

Figure 7 Effect of mixing time on the water content at 2/100 clays to oil ratio

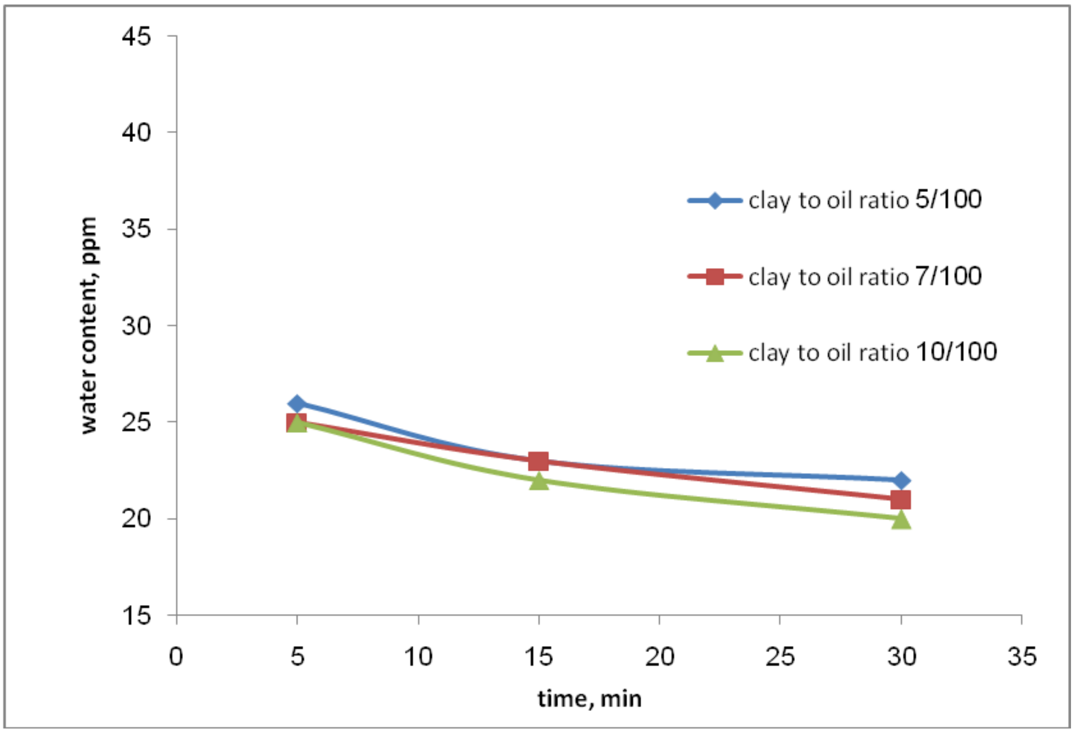

Figure 8 Effect of mixing time on the water content at 5/100, 7/100, 10/100 Algerian clay to oil ratios

- Effect of Algerian Clay to Oil Ratio on Break Down Voltage: Figure 9 shows the effect of clay to oil ratio on break down voltage at different contacting time. The more important conclusion from this figure that the increases in clay to oil ratio give decreases in break down voltage for the same duration time. This may be because the clay adsorbed the anti-oxidation additives presented in the oil.

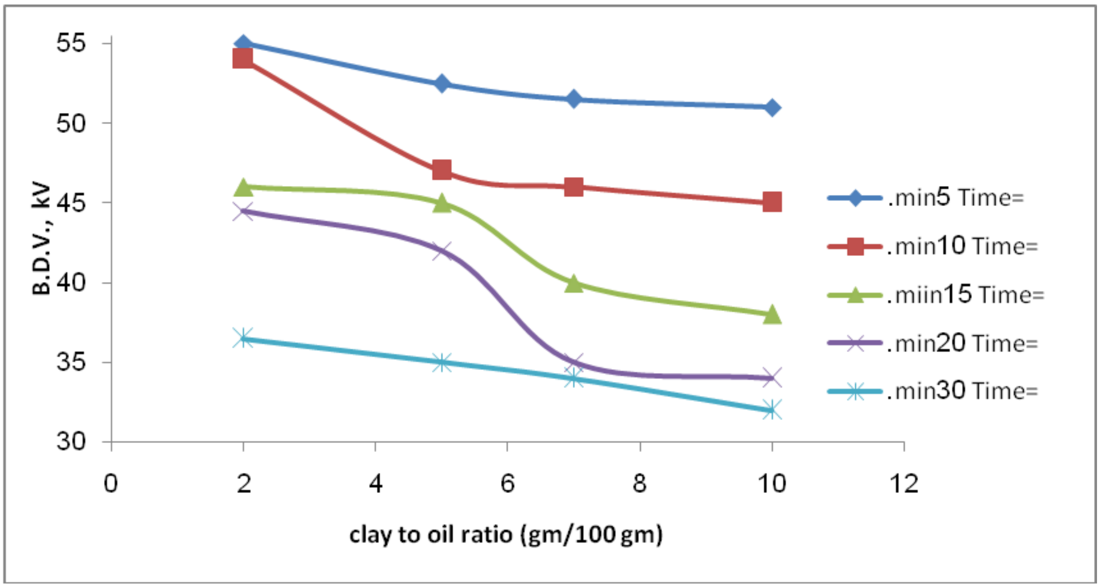

Figure 9 Effect of Algerian clay to oil ratio on the break down voltage at different mixing times

- Effect of Mixing Time on Break Down Voltage: Figure 10 shows the effect of mixing time on break down voltage. Whenever the mixing time increases, the break down voltage decreases at the same Algerian clay to oil ratio.

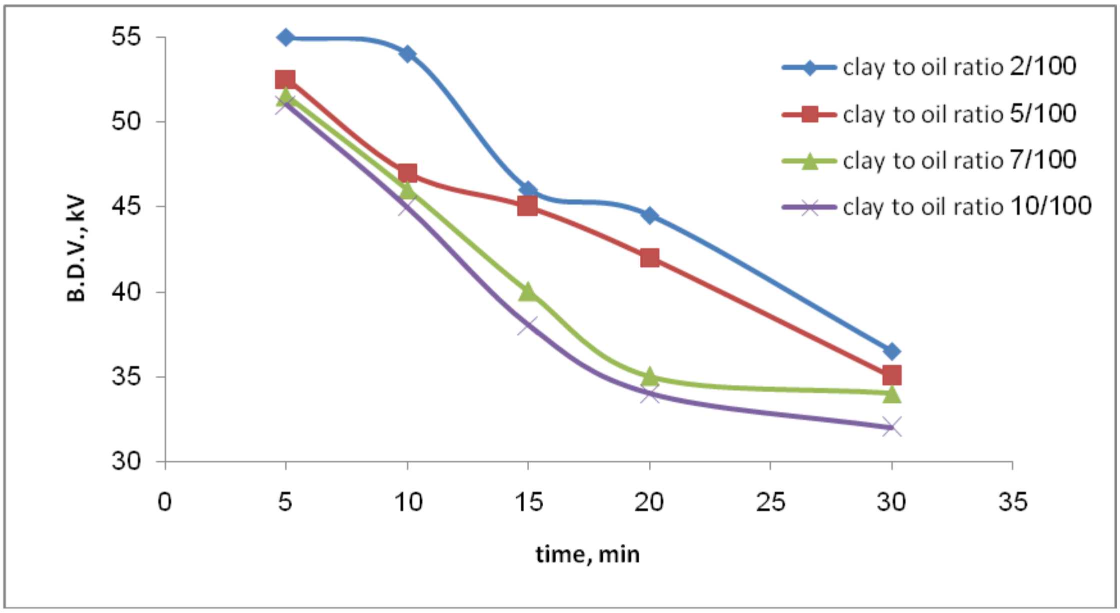

Figure 10 Effect of mixing time on break down voltage at different Algerian clay to oil ratios

- Acidity Values: Table 7 shows the acidity values for oil produced uses Algerian clay and zeolite treatments. The increasing of clay to oil ratio at constant duration time or increasing duration time for the same clay to oil ratio resulted a decrease in acid value of the oil. This is because the clay is a good adsorbent for the acidic impurities that found in the oil.

Table 7 Acidity values

No.	Clay to oil ratio	Time, min.	Acidity mg KOH/ gm oil
1	1/100	5	-
2		10	0.028
3		15	-
4		20	0.014
5		30	-
6	2/100	5	0.028
7		10	0.028
8		15	0
9		20	0.028
10		30	0.014
11	5/100	5	0.028
12		10	0.028
13		15	0.028
14		20	0.014
15		30	0.014
16	7/100	5	0.028
17		10	0.014
18		15	0.014
19		20	0
20		30	0
21	10/100	5	0.014
22		10	0.014
23		15	0
24		20	0
25		30	0
26	1/100 (zeolite)		-
27			0.028
28			-
29			0.014
30			-

- Color Improvement: The color of Algerian clay treated transformer oil with 10/100 clay to oil ratio was further improved by repeating clay treatment. The Algerian clay was used in this treatment using 35/100 clay to oil ratio and 80 ˚C for one hour. The color values for the spent oil, the oil treated in thermo vacuum evaporation and the improved color oil are 3.5, 6.3, and 0.4, respectively.

- Conclusion: The possibility of spent transformer oil regeneration was studied in four stages, these are settling, filtration, thermo vacuum evaporation, and clay treatment. Iraqi clay was used in 2/100 clay to oil ratio for 5 – 30 minutes duration time using a temperature 80 ˚C but it decreased the water content from 41 ppm to 39 ppm only. The study of Algerian clay treatment at 80 ˚C, duration time range 5 – 30 minutes and clay to oil ratio 1/100 – 10 /100 considerably decreases the water content. It could be considered that the best operating conditions for Algerian clay treatment are 2/100 clay to oil ratio and 5 minutes duration time. The values of water content, acidity and break down voltage in the above mentioned conditions were 32 ppm, 0.028 mg KOH/ g oil and 55 kV, respectively. Zeolite treatment at 1/100 zeolite to oil ratio and 5 – 30 minutes duration time using the same temperature (80 ˚C) gave worse improvement comparing with Algerian clay treatment. Freundlich and Langmuir isotherms and the combination of them were applied to calculate the adsorption rates and it was found that Freundlich adsorption isotherm well represented the adsorption of water on clay comparing with others isotherms.

REFERENCES

- Eklund, M., Sweden 2006, "Mineral Insulating Oils; Functional Requirements Specifications and Production", Nynas Naphthenics ABSE-149 82 Nynashamn, IEEE International Symposium on Electrical Insulation, 68-72.

- Hodgson, P., "Transformer Oil Processing", Redragon Oil & Gas Systems International Inc., Cambridge, Ontario, Canada www.redragon.com.

- Luki´c, J., Orlovi´c, A., Spiteller, M., Jovanovi´c, J., Skala, D., 2006, "Re-refining of waste mineral insulating oil by extraction with *N*-methyl-2-pyrrolidone", Separation and Purification Technology, 51, 150–156.

- Regional Activity Centre for Cleaner Production (RAC/CP), 2000, "Recycling Possibilities and potential uses of used oils".

- Basel convention technical guidelines on used oil re-refining or other re-uses of previously used oil no. 5, prepared by the technical working group of the basel convention and adopted by the third meeting of the conference of the parties to the basel convention in September 1995, Geneva.

- Zakharich, M., Zaitsev, I., Komar, V., Nikonovich, F., Ryzhkov, M. and Skornyakov, I., 2001, "Analysis of transformer oil using IR analyzers", Journal of Applied Spectroscopy, Vol. 68, No. 1, p 61.

- Groves, M. , 1990, " Maintenance Of Liquid insulation", power system maintenance manual, western.

- Lansdown, A.,1982, "Lubrication" first editon, Programon Press.