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The Impact of Temperature on the Regeneration of Used Engine Oil Using Attapulgite Clay as an Adsorbent

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Abstract
The primary objective of this study is to evaluate the effect of temperature on the removal of heavy metals contained in used engine oils. The treatment was carried out using a single contactor and modified Attapulgite clay as an adsorbent material. The modification of the Attapulgite clay consisted of mixing a solution of H_2SO4. Temperature of 50, 80, and 110 ºC was regulated into three different intervals to observe changes occurring in terms of the extraction of heavy metals. The results showed that iron Fe had the highest removal efficiency when compared to Zn, Cu, and Pb for all temperatures selected. At 50 ºC, Fe, Zn, Cu, and Pb had 55, 49, 48, and 46 respectively. At 80 ºC, Fe, Zn, Cu, and Pb had 53, 50, 49, and 43 respectively. At 110 ºC, the observed removal trend showed that Fe, Zn, Cu, and Pb had 53, 50, 49, and 43 respectively. The results indicate that acid clay process is not effective in removing heavy metals from used engine oils. This can be seen on the removal efficiency tabulated and graphical representation is below 75% for all metallic ions.
Keywords: Heavy metals, used oil, temperature, acid clay, attapulgite clay.

Introduction

Mismanagement of waste engine oil is among the highest contributors of environmental pollution challenges (Isah *et al.* 2013). This is due to lack of cost-effective methods to regenerate used oils. Waste engine oils contain heavy metals that have adverse effects on living and non-living organisms [2]. Therefore, it is important to mitigate improper management of waste engine oils to prevent an escalating amount of land pollution.

There are traditional and conventional methods of treating or removing the heavy metals in the waste engine oils. Traditional methods include neutralization with limestone or similar adsorbent that can extract the metallic elements. Conventional methods on the hand include the use vacuum distillation, solvent extraction, membrane technology, and acid-clay process [3]. Recent studies by (Raghuvir *et al.* 2018) indicate that conventional techniques are more preferred than traditional methods. However, the downfall of using conventional methods is high cost of operation and maintenance, poor removal efficiency, and generation of new pollutants [3].

Previous studies show that waste oil regeneration by means of conventional techniques is a front runner [2]. However, it remains unclear whether it's an effective solution which can be relied on to mitigate the environmental pollution. Further studies to be done in cost implications of waste oil regeneration or cost of maintenance and operation [7].

The primary objective of this study is to reflect on the impact of temperature on the removal of heavy metals contained in waste engine oils using attapulgite clay as an adsorbent material.

Methodology

For this study, all experiments were conducted in the Chemical Engineering laboratories at Mangosuthu University of Technology (MUT). Sample analysis by means of XRD, SEM, and BET were conducted at Witwatersrand University in department of Chemistry. Waste oil samples were retrieved from Dilex Chemicals.

Dilex chemicals is a liquid recycling organization located in New Germany North of Durban Kwa Zulu Natal. Dilex Chemicals collects various kinds of liquid wastes from different companies in and out of Kwa Zulu Natal.

Materials

Sieve trays, pH meter (Orion), Centrifuge, Hotplate (magnetic stirrer), and drier.

Method

Three 400 mL beakers filled with 100 mL of used oil were placed on top of each tripod (3 magnetic stirrer) to provide adequate heat supply while mixing the oil and the adsorbent (activated clay) to form a homogenous mixture. Contact time during each experimental run was set (10 - 60 minutes). In monitoring the heat required, a thermometer was used to measure the temperature of the mixture. The working temperature range was set between (60 – 90 degrees Celsius). Temperature played a vital role in reducing the viscosity of the oil allowing the activated to be in contact properly with the oil.

No additives were used to improve the color and the removal of the heavy metals. After every experiment conducted, a four-hour timeframe samples were allowed to cool off and settling to take place. Samples were then transferred to 250 mL conical flasks and filtered using a vacuum pump. Each flask produced three samples for accuracy and precision purposes. After filtration, samples were then transferred into 15 mL test tubes and placed into the centrifuge to allow proper separation of solids and liquids. Furthermore, this was to minimize any solid particles using FTIR. The centrifuge was set at 10 minutes interval separation and 4000 rpm rotation due to high viscosity therefore, a higher rotational speed is required to achieve optimum results.

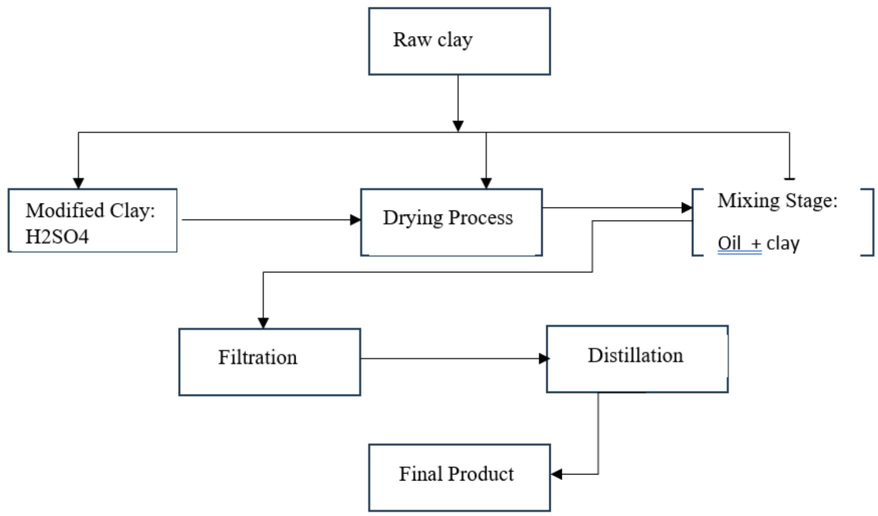

Figure 1: Acid-clay process with modified clay used as an adsorbent to extract heavy metals.

Results

Table 1 below shows the physical and chemical properties of used engine oils collected from the automotive industry before treatment. The data reveals the number of metallic ions present in used oil and its quantities in the form of concentration levels.

Table 1: Used oil characterization of physical and chemical properties before adsorption treatment (Adewole et al 2019).

Properties	**Used Engine oil from Toyota cars**	**Typical values**
Selected properties		
Density (g/mL)	1.078	0.98 – 1.13
Kinematic Viscosity at 40 °C (Pa.s)	1.27	1.07 – 1.33
Kinematic Viscosity at 100°C(Pa.s)	0.66	0.51 – 0.82
Viscosity Index	1.43	1.01 – 2.07
Ash Content %	0.10	0.10 – 0.18
Water Content %	1.85	0.97 – 1.91
Flash Point°C	177	1.70 – 181
Pour Point°C	93	88 - 97
Metallic Content (ppm)		
Lead (Pb)	52.67	28.53 – 60.15
Chromium (Cr)	65.10	5.75 – 92.14

Zinc (Zn)	66.36	12.38 – 81.02
Iron (Fe)	70.75	70.75 – 332.75
Nickel (Ni)	50.7	2.17 – 158.30
Copper (Cu)	44.17	4.33 – 143.33

Table 2 represents the physical and chemicals properties of used engine oil after treatment with modified attapulgite clay at 110 °C temperature.

Table 2: After treatment with Attapulgite clay at 110 degrees Celsius

Properties	Used Engine oil	Typical values
Selected properties		
Density (g/mL)	1.01	0.98 – 1.13
Kinematic Viscosity at 40 ℃ (Pa.s)	1.11	1.07 – 1.33
Kinematic Viscosity at 100℃(Pa.s)	0.79	0.51 – 0.82
Viscosity Index	1.50	1.01 – 2.07
Ash Content %	0.12	0.10 – 0.18
Water Content %	1.10	0.97 – 1.91
Flash Point℃	103	1.70 – 181
Pour Point℃	91	88 - 97
Metallic Content (ppm)		
Lead (Pb)	26.89	20.01 – 27.20
Chromium (Cr)	29.45	19.31 – 31.89
Zinc (Zn)	30.28	23.36 – 33.06
Iron (Fe)	37.09	34.11 – 44.07
Nickel (Ni)	22.70	19.47 – 27.30
Copper (Cu)	25.05	22.64 – 26.88

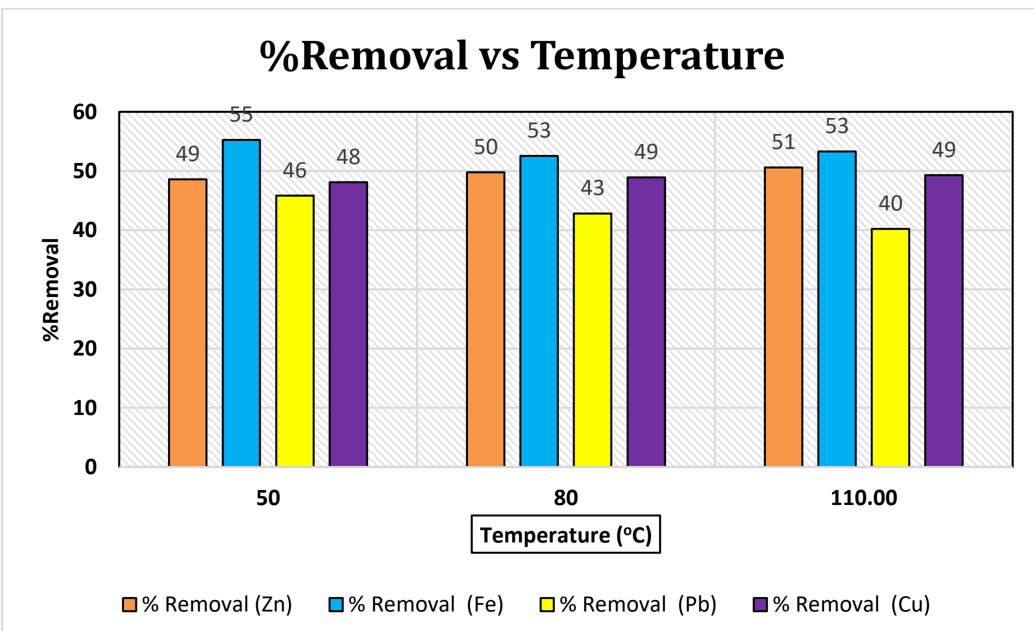

Figure 2: Percentage removal versus temperature.

The effect of temperature during the adsorption of heavy metals using attapulgite clay is moderately effective. Figure 4-1 shows that temperature-working parameter has a less impact on the extraction of metallic elements obtained in used engine oil. Highest removal percentage obtained being 55% for iron (Fe) at 50 degrees Celsius. The lowest percentage attained is 40% for lead (Pb). Lead however has the least removal efficiency compared to zinc, copper, and iron.

Table 3: Combination of operating conditions with temperature being regulated.

Parameters			**Heavy metal percentage removal**			
Temperature (^oC)	Clay dosage (Grams of clay/100ml oil)	Contact time (minutes)	Zn	Fe	Pb	Cu
80.00	25.00	50.00	44,55	43,86	37,52	43,89
80.00	25.00	50.00	44,55	43,86	40,87	43,89
110.00	25.00	90.00	41,31	42,14	31,49	36,19
50.00	25.00	10.00	51,03	66,22	50,25	54,67
50.00	10.00	50.00	62,37	69,66	52,93	57,75
80.00	40.00	10.00	46,98	66,22	54,27	60,83
80.00	10.00	90.00	57,56	50,74	34,84	40,04
80.00	25.00	50.00	45,51	54,18	44,89	53,13
80.00	10.00	10.00	72,09	71,27	55,61	63,91
50.00	25.00	90.00	41,31	40,42	35,51	35,42
80.00	40.00	90.00	46,17	35,26	31,49	32,34
80.00	25.00	50.00	42,93	54,18	40,87	49,28
110.00	10.00	50.00	59,13	61,06	47,57	54,67
110.00	25.00	10.00	60,67	61,06	48,91	59,29
110.00	40.00	50.00	41,31	49,02	32,83	46,97
80.00	25.00	50.00	47,79	53,32	44,89	53,13
50.00	40.00	50.00	39,69	44,69	44,597	44,504

The effect of temperature: The effect of temperature in the absorption of heavy metals by means of acid-clay process is significant. A high temperature is required to allow the extraction of metals to be effective. Hence, reducing the viscosity of the oil exposes the metals to inoculated or activated clay. This increases the attraction of ions. The minimum and maximum working conditions were set at 50-110 degrees based on previous studies conducted by various individuals. Lead (Pb) showed a great reaction response to the process having removed up to 90.07% at maximum conditions. While Cu, Cr, Ni also followed with removal efficiency greater than 75% reaching a high of 90.06%, 80.89% and 86.55% respectively. Zinc (Zn) and iron (Fe) had the least percentage removal compared to other metals.

Conclusion

The results obtained experimentally indicate or suggest that temperature has insignificant impact or effect on the removal of heavy metals on used engine oils. This shows that acid clay process alone cannot be relied upon for effective absorption of heavy metals, this indicated in the results obtained. However, various working combinations can be adjusted to determine if the yield significantly increases such as clay dosage and contact time. Further work needs to be done on clay medication to enhance the removal efficiency. Furthermore, work needs to be done on the energy consumption during the process to determine if the process is indeed viable or not. Lastly, the grey area that needs special attention is the uses of treated oils. Where can the treated oils be used, which industry or machinery can be suitable to use the final product obtained without adverse effects on it.

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