Adsorption of Metals (Zn, Ca and B) in Used Engine Oil by Using Microwave Incinerated Rice Husk Ash (MIRHA)

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Abstract Microwave Incinerated Rice Husk Ash (MIRHA), produced from the rice husk was proven as one of the low-cost materials that can be used as an adsorbent for heavy metal in aqueous solution. Used engine oil is one of the wastes that contain heavy metals, metals and other contaminants. Most are non- biodegradable and can harm living creatures and human being if not properly disposed. The aim of this research was to study the feasibility of using MIRHA as adsorbent for the removal of heavy metal, metals and other contaminants from used engine oil. The chemical composition of the used engine oil was determined based on ASTM D6595. A series of jar tests were conducted by varying the contact time at fixed concentration of MIRHA and varying the concentration of MIRHA at specified contact time. All the samples were conducted in triplicates. It was observed that the optimum contact time for zinc, calcium and boron removals at fixed concentration of adsorbent of 625,000 mg/L of MIRHA were found to be 4, 4 and 24 h, respectively. The percentage removals of zinc, calcium, and boron were found to be 38.24, 29.39 and 52.27 %, respectively. It was also observed that the optimum adsorbent dosage for Zn, Ca and B removals were at 450,000 mg/L of MIRHA with percentage removals of 55.12, 29.33 and 62.11 %, respectively.

Keywords Used engine oil · Metals · Heavy metals and contaminants · Adsorption · Microwave incinerated rice husk ash (MIRHA)

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1 Introduction

Wastes are unwanted material or any substance which constitutes a scrap material or an effluent or other unwanted surplus substances arising from the application of any process. The process may come from the industrial, commercial, household or any other process that has no economical demand and necessary to be disposed of properly [1].

Approximately 1.35 billion gallons of used oil are generated yearly and approximately 800 million gallons are collected by recyclers for reuse. Hence, only 59 % of the used engine oil were reused and 41 % were dumped away to the environment [2]. Used engine oil are composed of heavy metals that can caused hazards. The formation of hazards resulted from various additives used in its manufacture and from heavy metal contaminants picked up from internal combustion of engines. Used engine oil poured into household drains or directly onto the ground may lead into waterways and groundwater cause pollution [3]. According to Chevron, used motor oils do not present a significant inhalation health hazard. However, it can present a problem if they come in contact with the eyes or skin, triggering an allergic skin reaction or eye irritation. Long-term effects from repeated contact include a higher risk of developing skin cancer [4].

Rice Husk is a commonly available agriculture waste in Malaysia. It is estimated that, in South East Asia approximately 150 million tonnes (25 % of world production) of rice husk are being produced annually, 95 % of the production were used within the region and the remaining 5 % was exported to other countries [5]. Meanwhile, in Malaysia it is estimated that rice husk takes account for about 20 % of the whole rice produced [6]. According to the statistics compiled by the Department of Statistics Malaysia, [7] the production of Malaysia paddy in 2010 is 2,464,831 tonnes. Therefore, it is estimated that more than 400,000 tonnes of rice husk produced annually in Malaysia. The potential use of rice husk ash in the adsorption of metal ions has been widely investigated [8–10]. Microwave Incinerated Rice Husk Ash (MIRHA) obtained from burning the rice husk at controlled temperature using microwave incinerator have been studied and can be utilized as alternative adsorbent for removal of metal ions [11, 12].

Adsorption is considered as an efficient and economically feasible method to remove or treat heavy metals present in used engine oil. The use of rice husk as adsorbents is an option for cheap and readily available sources than activated carbon, since rice husk are one of the agricultural waste which are abundant in Malaysia. The aim of this research was to study the feasibility of using MIRHA as an adsorbent for the removal of heavy metal and other contaminants from used engine oil.

Table 1 Typical chemical composition of MIRHA [13]

Chemical composition	Weight %
Na_2O	0.0195
MgO	0.5885
Al_2O_3	0.3572
SiO_2	86.3115
P_2O_5	3.008
K_2O	6.3366
CaO	0.9996
TiO_2	0.0191
Fe_2O_3	0.7227
SO_3	1.5145
MnO	0.1301

2 Methodology

2.1 Preparation of Microwave Incinerated Rice Husk Ash

Rice Husk was collected from BERNAS Rice Mill in Seberang Perak, Malaysia. The rice husk was burned at 500 °C (MIRHA) temperature for 8 h. Table 1 illustrates the chemical composition of MIRHA [13].

2.2 Source of Raw Used Engine Oil and Initial Analysis

Raw used engine oil was collected from several car service centres in Perak, Malaysia. All of the raw used engine oil was mixed and the initial elemental analysis of raw used engine oil was analyzed. Table 2 illustrates the elemental analysis of raw used engine oil.

2.3 General Experimental Procedure

The chemical composition of the used engine oil was determined based on ASTM D6595 (Standard Test Method for determination of wear metals and contaminants in used lubricating oils or used hydraulic fluids by rotating disc electrode atomic emission spectrometry). Two sets of jar tests were conducted using the used engine oil. The final chemical composition or wear metals of the used engine oil after the jar tests were measured based on ASTM D6595 procedure. For each metal, optimum contact time and optimum dosage of MIRHA to be added for the adsorption process was evaluated.

Table 2 Initial elemental analysis of raw used engine oil

Type of elements	Metals elements in ppm unit
Iron (as Fe)	26.5
Chromium (as Cr)	1
Lead (as Pb)	2
Copper (as Cu)	9
Tin (as Sn)	<1
Aluminium (as Al)	6.5
Nickel (as Ni)	<1
Silver (as Ag)	<1
Silicon (as Si)	16
Boron (as B)	47.5
Sodium (as Na)	102
Magnesium (as Mg)	99
Calcium (as Ca)	1581.5
Barium (as Ba)	2
Phosphorous (as P)	567
Zinc (as Zn)	944
Molybdenum (as Mo)	33.5
Titanium (as Ti)	<1
Vanadium (as V)	1.5
Manganese (as Mn)	2.5
Cadmium (as Cd)	<1

2.4 Procedure on Effect of Contact Time at Fixed Adsorbent Dosage

In this jar test, a constant concentration of MIRHA at 625,000 mg/L were stirred with 800 mL of used engine oil at contact times of 4, 8, 14 and 24 h. Three jars were prepared for each contact time.

2.5 Procedure on Effect of Adsorbent Dosage (Concentration) at Fixed Contact Time

In this jar test, the adsorbent (MIRHA) was varied at 0.20, 0.28, 0.36, 0.40, 0.44, 0.52, 0.60 kg and stirred with 800 mL of used engine oil at a constant contact time of 24 h. Three jars were prepared for each weight of adsorbent.

3 Results and Discussion

3.1 Effect of Contact Time at Fixed Adsorbent Dosage

Based on the experiment, total of 21 metals which consist of Fe, Cr, Pb, Cu, Sn, Al Ni, Ag, Si, B, Na, Mg, Ca, Ba, P, Zn, Mo, Ti, V, Mn, Cd were found in raw used engine oil. Out of these, 10 types of metals were recognized to be significantly affected by MIRHA. The metals adsorbed were Fe, Al, Si, B, Na, Mg, Ca, P, Zn, and Mn. Table 3 show the removals for the 10 elements. It was observed that some elements increased in concentration while some are removed. The elements

Table 3 Behaviour for the affected elements due to contact time variation

Type of elements	Contact time (hour)	Final conc. of element (ppm)	Initial conc. of element (ppm)	Difference between initial and final conc. (ppm)	Effect of MIRHA to the elements based on contact time variation	Reasons of differences between the initial and final conc. of elements
Iron (as Fe)	24	107.00	26.5	+80.5	Slightly affected	Occurrence of Fe_2O_3 in MIRHA
Aluminium (as Al)	24	21.67	6.5	+15.17	Slightly affected	Occurrence of Al_2O_3 in MIRHA
Silicon (as Si)	24	3339.33	16	+3323.33	Much affected	Occurrence of SiO_2 in MIRHA
Boron (as B)	24	22.67	47.5	−24.83	Slightly affected	Adsorbed by MIRHA
Sodium (as Na)	24	88.00	102	−18.33	Slightly affected	Adsorbed by MIRHA
Magnesium (as Mg)	24	329.00	99	+230	Affected	Occurrence of MgO in MIRHA
Calcium (as Ca)	4	1116.67	1581.5	−464.83	Affected	Adsorbed by MIRHA
Phosphorous (as P)	14	1882.67	567	+1315.67	Affected	Occurrence of P_2O5 in MIRHA
Zinc (as Zn)	4	583.00	944	−361	Affected	Adsorbed by MIRHA
Manganese (as Mn)	14	53.67	2.5	+51.67	Slightly affected	Occurrence of MnO in MIRHA

increased in concentration due to their presence in the adsorbent (MIRHA). The elements that were significantly adsorbed were Ca, Zn and B.

3.2 Effect of Adsorbent Dosage at Fixed Contact Time

Based on the experiment, total of 21 elements of metals which consist of Fe, Cr, Pb, Cu, Sn, Al Ni, Ag, Si, B, Na, Mg, Ca, Ba, P, Zn, Mo, Ti, V, Mn, Cd were found in raw used engine oil. Out of these 10 metals were significantly affected by MIRHA. The metals affected were Fe, Al, Si, B, Na, Mg, Ca, P, Zn, and Mn. Table 4 show

Table 4 Behaviour for the affected elements due to concentration variation

Type of elements	MIRHA concentration (mg/L)	Final conc. of element (ppm)	Initial conc. of element (ppm)	Difference between initial and final conc. (ppm)	Effect of MIRHA to the elements based on contact time variation	Reasons of differences between the initial and final conc. of elements
Iron (as Fe)	750,000	137.3	26.5	+110.8	Affected	Occurrence of Fe_2O_3 in MIRHA
Aluminium (as Al)	750,000	48.33	6.5	+41.83	Slightly affected	Occurrence of Al_2O_3 in MIRHA
Silicon (as Si)	650,000	3268.7	16	+3253	Much affected	Occurrence of SiO_2 in MIRHA
Boron (as B)	450,000	18	47.5	−47.18	Slightly affected	Adsorbed by MIRHA
Sodium (as Na)	250,000 and 750,000	76 and 140.33	102	−26, and +38.33	Slightly affected	Adsorbed by MIRHA
Magnesium (as Mg)	750,000	630	99	+531	Affected	Occurrence of MgO in MIRHA
Calcium (as Ca)	450,000	1117.7	1581.5	−463.8	Affected	Adsorbed by MIRHA
Phosphorous (as P)	750,000	2744.7	567	+2177.7	Much affected	Occurrence of P_2O5 in MIRHA
Zinc (as Zn)	750,000	423.7	944	−520.3	Much affected	Adsorbed by MIRHA
Manganese (as Mn)	450,000	149.7	2.5	+147.2	Affected	Occurrence of MnO in MIRHA

the behaviour for the 10 affected elements at various adsorbent dosage. It was observed that some of the elements increased in concentration while some are removed through adsorption. The elements that were significantly adsorbed were Ca, Zn and B.

3.3 Removal Efficiency of Zn, Ca and B at Fixed Adsorbent Dosage (625,000 Mg/L) and Variation of Contact Time

From the 10 affected elements it was observed that only Zn, Ca, B were significantly adsorbed by MIRHA. The removals of the metals through adsorption of MIRHA was plotted in Fig. 1. It was also observed that the optimum contact time for zinc, calcium and boron removals at fixed concentration of adsorbent of 625,000 mg/L of MIRHA were found to be 4, 4 and 24 h, respectively. The removals of Zn, Ca, and B were found to be 38.24, 29.39 and 52.27 %, respectively.

3.4 Removal Efficiency of Zn, Ca and B at Fixed Contact Time and Variation of Adsorbent Dosage

From the 10 affected elements it was observed that only Zn, Ca, B were significantly adsorbed by MIRHA. The removals of the metals through adsorption of MIRHA was plotted in Fig. 2. It was also observed that the optimum adsorbent dosage for zinc, calcium and boron removals were at 450,000 mg/L of MIRHA with removals of 55.12, 29.33 and 62.11 %, respectively.

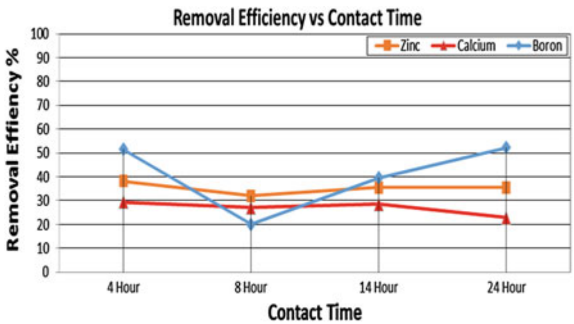

Fig. 1 Removal efficiency versus contact time

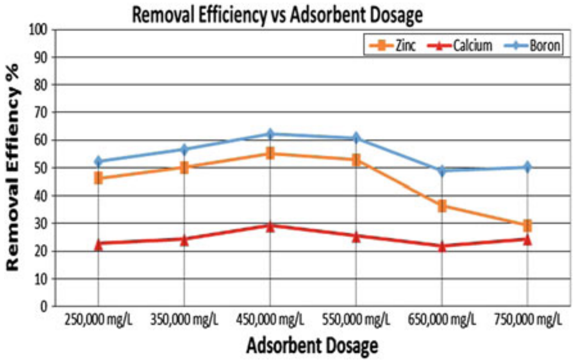

Fig. 2 Removal efficiency versus adsorbent dosage

4 Conclusion

From the study, it can be concluded that MIRHA has the ability to adsorbed metals such as Zn, Ca, and B in used engine oil. The removals of these metals will further improve in recycling of used engine oil as a potential superplasticizer in concrete.

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