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Treatment of Oil Spill by Adsorption onto Activated Rice Husk and E-Waste

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Abstract*: A tremendous rise in off-shore oil production, transportation of petrochemicals, and regular oil spillage contribute to environmental problems in the marine environment. Adsorption is one of the effective methods that are used to remediate oil spill. One of the potential adsorbents is rice husk. In this project, rice husk is used as an adsorbent and is activated with stearic acid. Also, the activated non-metallic fraction of e-waste acts as a suitable additive that could increase the adsorption. The adsorbents' preparation processes were optimized as the time of pyrolysis, Pyrolysis temperature, and concentration of stearic acid (SA) is optimized for maximum oil adsorption. Also, their morphology and composition are studied using FTIR, SEM, EDS, and BET Analysis and using the data of oil adsorbed, various isotherms such as Freundlich, Langmuir, and Redlich Peterson isotherms are plotted, which could be used to find the model that suits this adsorption data. It was found that when activated e-waste was mixed with Activated Rice Husk in the ratio 1:10, it adsorbs 50% of the oil present in a 50 ml oil-water mixture. The equilibrium adsorption data of oil on the adsorbent mixture were analyzed by Langmuir, Freundlich, and Redlich - Peterson isotherm models. The isotherm that fits the experimental data the best is the Freundlich isotherm model. The monolayer adsorption capacity (q_{max}) was 428 mg/g. Pseudo-first-order, pseudo-second-order, and intra particle diffusion models were used to evaluate the kinetic data. The model that fits the experimental data the best is Pseudo-first-order kinetic model. Thus, the adsorbent mixture has the potential to remove oil in marine environment as both of the adsorbents used are discarded mainly as waste, there is an addition of value as these "waste" products could be utilized to combat one of the most convoluted problems of this modern era.

***Keywords*: Adsorption, Adsorption isotherms, e-waste, Oil spill, Remediation, Rice husk.**

1. Introduction

A. Oil spill

Over the last few decades, the exponential growth of human residents on earth ultimately results in extensive resources expenditure, and the continuing progress of human development has been accompanied by modernization [12]. Due to its adverse effects on human health and the ecosystem, there is an increased demand for systems to remove oil and other organic pollutants from various water sources [40]. In recent decades, the after-effects of oil spills on the ecosystem show that this problem could cause catastrophic, irreversible effects on the environment. The largest commodity exported globally is oil.

In 2018, oil had accounted for 5.9% of the global value of all exported products. Saudi Arabia is the highest exporter of oil, responsible for 16.1% of global oil exports in 2018, for a total of $182.5 billion in value. Oil Consumption of India was slated to be 5,155.747 Barrel/day in December 2018. This shows an increasing trend from the previous number of 4,869.763 Barrel/day for December 2017 [39]. Annually, oil consumption globally is even more extraordinary, reaching 36.4 billion barrels consumed in 2018, according to B.P. (British Petroleum Report, 2019). That's oil consumption worth $2.184 trillion in a single year. Thus, oil transport is essential, and rarely, the damage of transport leads to an oil spill. Our aquatic ecosystem is endangered due to oil spillage from different situations [23]. Oil spills have a permanent effect on the environment because of the noxious substances that are released into them. The production and consumption of petroleum products are swelling globally, and as a deleterious effect of transportation and its associated processes, oil spills are unfortunately increasing accordingly. In 1989, Exxon Valdez, the ship that spilled over 750000 barrels of oil in the Pacific Ocean [15]. In 2010 this was masked by the Deep Water Horizon oil spill, which resulted in the loss of 4900000 barrels of oil [14]. Diwakar. S *et al.* 2017 inferred that the oil spill in rivers, lakes, backwaters make it unsuitable for drinking and irrigation. The cleanup of the oil spill is based on many factors like temperature, the amount of oil spilled. On average, it can take months or even years to clean up this oil spill [9]. One of the methods for removing oil spills is adsorption. The use of adsorbents is one of the ways with maximum effectiveness due to its small price, comfortable, swift operation, and reusability. Meanwhile, the adsorption technique has the potential to be applied in mega-scale treatments to remediate the oil spill [11]. Thus activated rice husk (ARH) and e-waste could be utilized as waste management is difficult as humongous amounts of these wastes are produced in India.

B. Methods of oil spill remediation

For remediating oil spills, different methods are used to treat them in the ocean. The methods that are used majorly to treat oil spills are dispersion, Centrifugation, Bioremediation, and

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adsorption [2]. In dispersion, a surfactant is used to disperse larger molecules of oil into smaller ones as smaller molecules could degrade quickly. But, the smaller molecules do not degrade easily, and this method is effective only in masking the oil spill [6]. Bioremediation could altogether remove the oil spill, but oil recovery after degradation is difficult. In centrifugation, although the oil could be reused, the probability of oil mixing with water during separation is very high [15]. Thus, adsorption results in the removal of oil spill efficiently as it doesn't have the drawbacks that the other methods mentioned above have.

C. Choice of rice and e-waste as adsorbent

There are various adsorbents that are used for oil adsorbents. The adsorbents used here are activated rice husk and activated e-waste. The reason why rice husk is used is that rice contains 16% - 18% of rice husk by weight, and our country has exported 75, 99,552.15 Metric Tonnes of rice to the world for the worth of Rs. 21,184.85 crores / 3,047.78 Million dollars during the financial year 2018-19 [32]. Thus, it is evident that rice husk is produced in a large amount that could be utilized. Also, there are studies that prove its reliability as an adsorbent. Seiji *et.al.* 2007 concludes that carbonized rice husk could be used for oil adsorption as a high amount of heavy oil is adsorbed by the carbonized rice husk [33]. Kwang *et.al.,* 2019 concluded that rice husk contains 95–98% of silica by weight, which could explain its adsorption characteristics [25]. Gupta *et.al..* .2010 [26] studied that the rice husk is a cheap and readily available material, which can act as a better replacement for activated Carbon (A.C.). Thus; rice husk is efficient as it is easy to procure, easy to process, and also an efficient adsorbent of crude oil. The reason for choosing activated e-waste is similar to that of rice husk. E-waste production in India is around 2 million tonnes in 2018 [19]. Thus, e-waste production is also abundant in developing nations like India due to the large volume of discarded electronics. In e-waste, the metals are recovered that could be recycled. But, the plastics are powdered and stored as they don't have any use. But, in recent years, there had been studies to prove that it could be an adsorbent. Hadia *et al.*,.2013 suggest the usage of a non-metallic fraction(NMF) of e-waste for adsorption of heavy metal adsorption, and thus, the non-metallic fraction of e-waste is a prospective adsorbent [31]. Thus, e-waste is activated and used as an adsorbent. But, raw adsorbents have lower exposed surfaces, and hence they are needed to be activated.

D. Activation of the adsorbent for adsorption

The reason for activation is that the adsorbent should be selectively adsorbing the adsorbate so that its efficiency increases. In the case of an oil spill, the adsorbent should not adsorb water. To prove that, Norizan Ali *et. al.* 2011 reports that the natural adsorbent should be extremely hydrophobic or lipophilic so that oil selectivity over water is preserved, which results in selective adsorption of oil [28]. To activate the adsorbents, they are pyrolyzed as their adsorption efficiency increases as the study in Kenes *et.al.*.2012 reports pyrolyzed adsorbents centered on rice husks as an effective adsorber for crude oil since they have high permeability and have reactive functional groups in the surface including carbonyl, methylene and carboxyl groups [21]. To activate the adsorbents, Stearic Acid (SA) is used, which is studied in Diwakar *et al.* 2017 [9]. This research suggests the use of SA as an activating agent for hydrophobicity of the adsorbent. This is because its selectivity towards oil could be increased after activation. Thus, the adsorbents are activated and used in the experiment. As we had already seen about the reason for using rice husk as an oil adsorbent, the activation of rice husk also plays a crucial role. The esterification reaction happens between the stearic acid and silanol which results in the loss of water molecule as the stearic acid solution is alcoholic and the ester is formed which results in the blockage of hydrophilic hydroxyl group in silanol, making it hydrophobic and lipophilic [17].

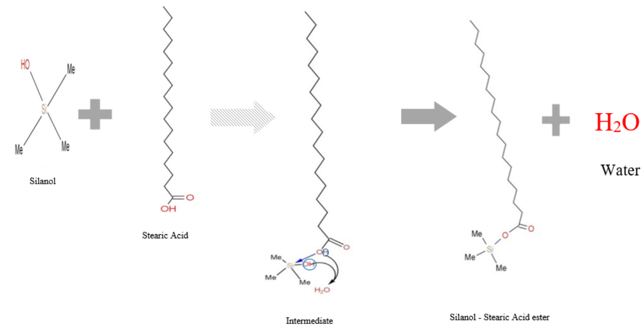

Fig. 1. Mechanism of Stearic acid and Silanol esterification

2. Materials and Methods

A. Materials required

Rice husk was procured from Pudupadi Village, Ranipet district, Tamil Nadu, and non-metallic fraction of e-waste were obtained from SEZ Recyclers, Mahindra City, Chengalpattu district and Victory Recyclers., Kottiyur Village, Tiruvallur District. Oil was procured from a mechanic shop in Guduvancheri, and seawater was procured from Marina Beach, Chennai.

B. Rice husk pretreatment

Wash the rice husk and remove the impurities such as plastics and dry the rice husk completely. Pyrolyze the rice husk at 450oC (optimized in this study). Treat the rice husk with 30mM SA (optimized in this study). Incubate it for 3hours in the oven at 120^{o} C. Wash the excess SA with N-Hexane and dry it for 30 minutes in the oven at the same temperature.

C. E-waste pretreatment

Take the non-metallic fraction of E-waste and make sure it is devoid of any moisture by drying it. Then, Pyrolyze it at 400°C for 3hours. Treat the E-waste using a 30mM concentration of SA and incubate it for 3hours in the oven at 120^{o}C. Wash the excess SA with N-Hexane and dry it for 30 minutes in the oven at the same temperature.

D. Optimization of Temperature of Pyrolysis and Concentration of SA upon rice husk

1) Temperature

The Rice husk was pyrolyzed at various temperatures from

350°C to 550°C for various time intervals (1 hr., 2 hrs. and 3 hrs.), and oil adsorption was observed at each temperature.

2) The concentration of SA

When the rice husk is in contact with the oil-water mixture, it absorbs both oil and water. This process aims to make the rice husk adsorb only oil, and thus, rice husk has to be made hydrophobic, and for that, both the rice husk and E-waste with SA are treated with various concentrations of SA that were prepared(10mM,20mM,30mM,40mM,50mM). 10mM SA was prepared by dissolving 0.284 g SA in 100ml Ethanol and mixed thoroughly. Similarly, 20mM, 30mM, 40mM, 50mM SA was prepared by dissolving 0.568g, 0.852g, 1.136g, and 1.420g of SA crystals in 100 ml Ethanol, respectively.

E. Preparation of adsorbate mixture and adsorbance experiment

In a 250 ml beaker, add oil and seawater in the ratio of 1:10 (5ml of oil to 50 ml of water) [9]. To the oil-water emulsion, add 1 gram Activated E-waste (AEW) and Activated Rice husk(ARH) (0.1 g AEW:0.9 g ARH) mixture. Allow it to stand for 10 minutes with occasional mixing so that the entire surface of the particles comes in contact with the motor oil. Then, remove the adsorbent mixture and leave it at room temperature for a minute so that the excess oil drains off. Then, it is weighed, and the difference in weight is the amount of oil adsorbed by the adsorbent mixture [4]. The same experiments were carried out using raw RH, and SA treated RH for control.

F. Addition of e-waste to activated rice husk

E-waste is added to Activated Rice Husk at different ratios (0.1g AEW:0.9g ARH, 0.2g AEW:0.8g ARH,0.3g AEW:0.7 g ARH) and the previous experiment is carried out, and its oil adsorption was recorded.

G. Characterization of adsorbent and adsorbate

Fluid dynamics of oil: Since the oil's fluidic properties are not known, its density and kinematic viscosity are found out by testing the oil in a lab. The sample was given to Bureau Veritas India Pvt. Ltd., Guindy for analysis.

Gas Chromatography: Gas Chromatography is used to detect organic functional groups in the motor oil. For this analysis. 1 ml of motor oil was diluted with 10 ml of n- hexane to increase the volatility of the motor oil sample, and gas chromatography was done according to the reference to Dominguez-Rosado *et.al.* 2003. The underlying principle of gas chromatography is that compounds that have a more significant attraction for the stationary phase stay for more time in the column and thus, elute later and have a longer retention time (R_t) than samples that have a higher attraction towards the mobile phase. A Bell-shaped curve was obtained [10].

BET Analysis: Brunauer-Emmett-Teller analysis is used to deduce the surface area that is available for adsorption. Two samples were given for BET analysis. One sample was not treated with SA, and the other sample was treated with SA. Both of them were crushed mechanically and then given for analysis. In BET Analyser, the samples are vacuum dried. The volume of gas adsorbed by the particles' surface is calculated at -196°C. The gas adsorbed is interrelated to the whole surface area of the particles. The enumeration is based on the BET theory. The precise surface area of particles is established by the physical adsorption of a gas on the surface of the solid. By computing the amount of adsorbate gas resultant to a monomolecular layer on the surface [7].

SEM: Scanning Electron Microscopy is used to observe the topology of the sample, and similar to BET Analysis, two samples were subjected to the same treatment as in the BET Analysis and, it is observed under Scanning Electron Microscope. The images are observed, and the change effected by SA is studied, the principle of Scanning Electron Microscope is that the secondary electron that is emitted passes through the condenser, objective lens, and other filters so that only one wavelength of the electron is passed through the sample. The sample absorbs the energy and reaches higher excitation from the ground state, which is detected by a detector. It is then converted to an image using software, and the image is viewed. [36].

EDS: EDS is an analytical method that is conducted for the elemental analysis and chemical characterization of a sample. The underlying principle of Energy- dispersive X-ray spectroscopy is that the electrons are bombarded in the sample. These electrons excite the sample, which results in excitation of the elements existing in the sample, and each element emits distinct energy, which is detected by a detector, and the peaks are recorded. When compared with standard, different elements could be found with ease. The electrons are in the form of X Rays, and thus elemental analysis could be done.

FTIR: Fourier Transmission Infrared Spectroscopy is a spectroscopy method in which a wide range of Infrared light is passed from 400 cm-1 to 4000 cm-1, and each organic bond gets excited at a particular wavelength which is detected, and a peak is shown at that wavelength, and when compared with the standards, the functional groups in the sample could be deduced [41].

Isotherms: From the oil adsorption data recorded, Langmuir, Freundlich, and Redlich Peterson equation are plotted, and the models are compared with each other, and the model that this experiment follows is deduced by finding the "r" value.

1. Langmuir Isotherm: The linearized equation for Langmuir adsorption isotherm is as follows,

$$c_e/q_e = 1/q_m{*}\ K_{L.} + c_e/q_m$$

c_e is the equilibrium concentration of the adsorbate, q_e is the adsorption capacity adsorbed at equilibrium, qm is maximum adsorption capacity, and K.L. is the Langmuir adsorption constant.

2. Freundlich isotherm: The linearized equation for Freundlich adsorption isotherm is as follows.

$$\log(^{x}/m) = \log(k) + 1/n{*}\log C$$

Where, x is the mass of adsorbate, m is the mass of adsorbent, C is the equilibrium concentration of adsorbate in the solution [24].

Redlich Peterson isotherm: The linearized equation for

Redlich Peterson adsorption isotherm is as follows.

$$\ln (c_e/q_e) = \beta \ln(C_e) - \ln (A)$$

Where c_e is the equilibrium concentration of the adsorbate, and q_e is the adsorption capacity adsorbed at equilibrium [16].

3. Results and Discussion

A. Optimization of Temperature of Pyrolysis and Concentration of SA upon rice husk

The effect of temperature on oil adsorption was studied, and It was observed that when the rice husk was pyrolyzed at 450°C for 1hour, there was maximum adsorption of oil. When pyrolyzed at 350ºC, rice husk did not pyrolyze properly, and temperatures above 500ºC resulted in charring of the rice husk. Also, the charring of rice husk occurred when it was pyrolyzed at more than one hour.

The effect of SA concentration on oil adsorption, both the adsorbents were studied, it was observed that when both the adsorbents were treated with 30mM SA. When it was treated with 40mM and more, the efficiency of oil adsorption decreased.

To deduce the more significant parameter within the two of them; namely, the temperature of pyrolysis and concentration of SA, 2 Way ANOVA analysis was done, and it was found that the change in temperature was significant and the change in the concentration of SA was insignificant according to F Test. (Table 1).

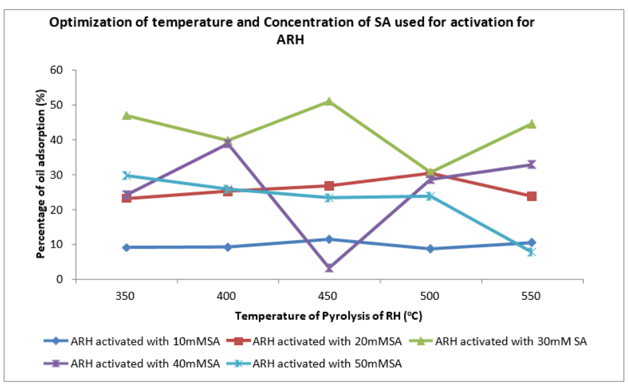

Fig. 2. Concentration of SA vs. Percentage of oil removal for 350^0C-550^0C pyrolysis temperature of Activated Rice Husk

B. Preparation of adsorbate mixture

Oil adsorption data were collected for different conditions, and as fig. 3, graph clearly shows that over 50% of oil removal was possible at rice husk pyrolyzed at 450ºC for 1 hour and then treated with 30mM SA. And the maximum oil adsorbed was 4g of the adsorbent.

C. Addition of e-waste to activated rice husk

It was observed that 0.1:0.9 ratio of activated e-waste and activated rice husk increased oil adsorption, after which it reduced, which could be seen in the graph below. Thus, the adsorption is increased by 0.6g/g of adsorbent, and therefore, e-waste, when activated, acts as an efficient additive.

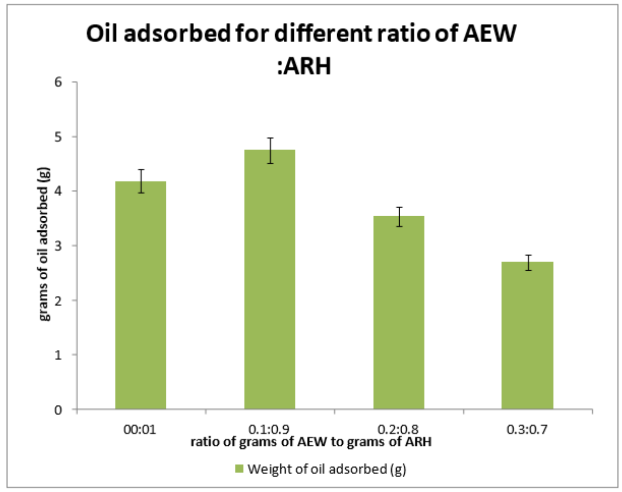

Fig. 3. Oil adsorbed for different ratio of AEW: ARH

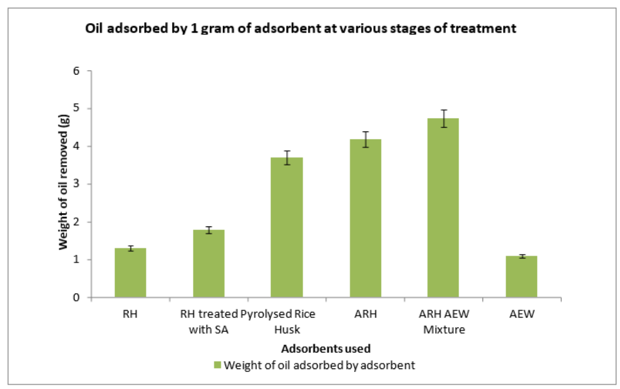

Fig. 4. Oil adsorbed at different stages of treatment of adsorbent

D. Characterization of adsorbent and adsorbate

Fluid properties of oil: The motor oil's fluid properties were found out. Its density was found to be 0.8683 g/cc, and it' viscosity was found to be 0.067 Ns/m^2. This data was used in calculating the weight of the oil.

Gas Chromatography: Gas Chromatography was performed, and there were various functional groups, and there were many peaks that were recorded as seen in fig. 5. After performing Gas Chromatography, Mass Spectroscopy was performed and there were over ninety organic compounds and a few inorganic compounds and the numbers of aromatic compounds were marginally higher than that of aliphatic compounds as seen in fig. 6. The most abundant compound was found to be Ethyl Benzene and thus, motor majorly consists of aromatic

Table 1
Two-way ANOVA table for both of the above temperatures

Source of Variation	Source of Variation	Degrees of freedom	Mean Square	F-Calculated	F critical
Temperature	5.671081	4	1.41777	22.26566	3.006917
Concentration	0.157563	4	0.039391	0.618622	3.006917
Error	1.018803	16	0.063675		
Total	6.847447	24			

compounds and as we know that aromatic compounds are carcinogenic and toxic to the environment, motor oil should not be discarded in the sewage systems as it would contaminate the environment (Dreij et al. 2019).

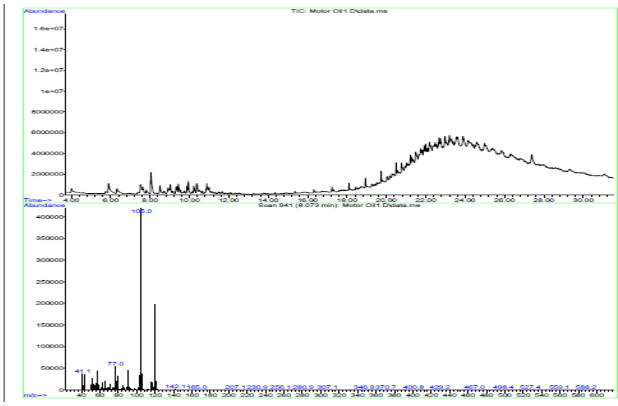

Fig. 5. Gas chromatography graph (Top) and Mass spectroscopy sample graph of Methyl Propyl Benzene (Bottom)

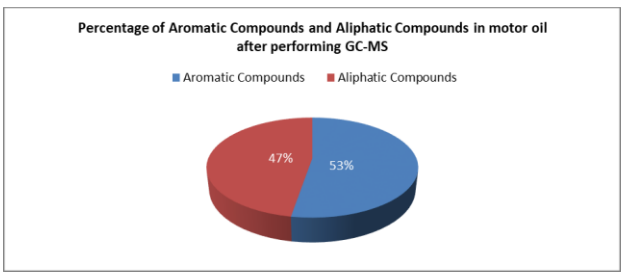

Fig. 6. Percentage of Aromatic Compounds and Aliphatic Compounds in motor oil after performing Mass Spectroscopy

BET Analysis: BET Analysis showed that the surface area of adsorbent doubled when treated with SA. Before treating with SA, the surface area was 25 m^2/g, and after SA treatment, it increased to 46 m^2/g. Although Activated Carbon has an area of 100 m^2/g to 300 m^2/g, the adsorbent could be pulverized by machines that are available on an industrial scale and thus could result in fine powder, which has a relatively larger surface area.

SEM analysis: Similar to BET Analysis, the adsorbent treated with SA and sample before the treatment of SA. The observation made was that when the adsorbent is treated with SA, the pores were visible when compared to the other, as seen in fig. 6 and 7. In similar research, rice husk was treated with NaOH, which resulted in an increase in pore size [1]. Thus, it can be concluded that SA treated adsorbent could adsorb more oil, justifying the SA activation.

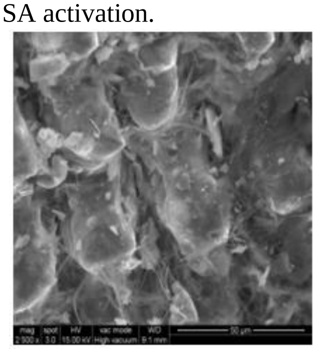

Fig. 7. SEM image of pyrolyzed RH

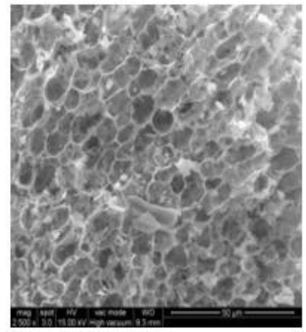

Fig. 8. SEM image of SA

EDS: The same samples as that of SEM underwent EDS, and the elemental composition changed as Silicon content increased. The increase in Si could be hypothesized that the SA reacted with the organo-silanol that is a hydroxide of Silicon. It is known that rice husk has a high percentage composition of Silicon in the form of Silanol [42]. SA could have reacted with Silicon to form a complex which could have increased the Silicon in EDS.

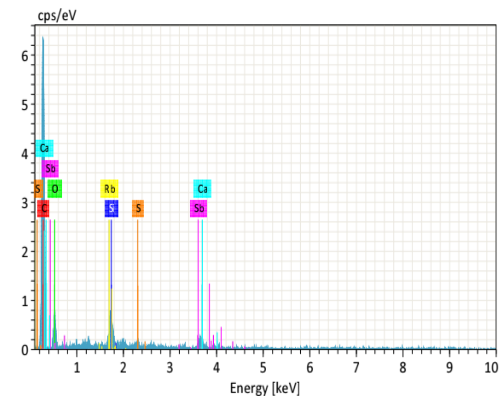

Fig. 9. EDS of Raw RH

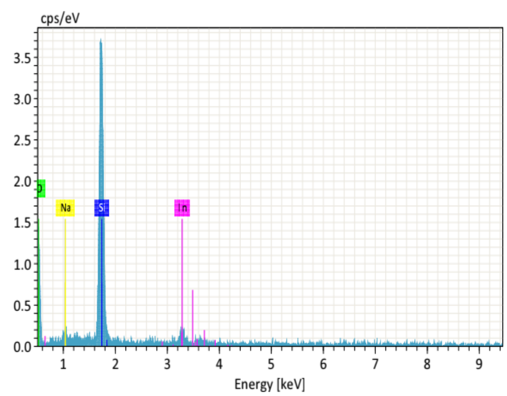

Fig. 10. EDS of ARH

FTIR: Five samples of adsorbent were taken. One is activated Carbon, and the other is the Activated Rice Husk (ARH), and the rest are pyrolyzed rice husks for different time intervals. There was a significant distinct peak in ARH at 1770 cm^{-1} as seen in fig. 11. which, when compared with the standard for bond nature, shows C=O stretching bond which corresponds to ester bond [16], which supports the previous hypothesis made in EDS about Silanol–SA complex. The remaining FTIR graphs of rice husks, pyrolyzed at different temperatures, and the activated Carbon do not have a peak at 2360 cm^{-1}. The similar peaks for all the graphs are at around 1050 cm^{-1}, which showcases the presence of Sulphoxide [5].

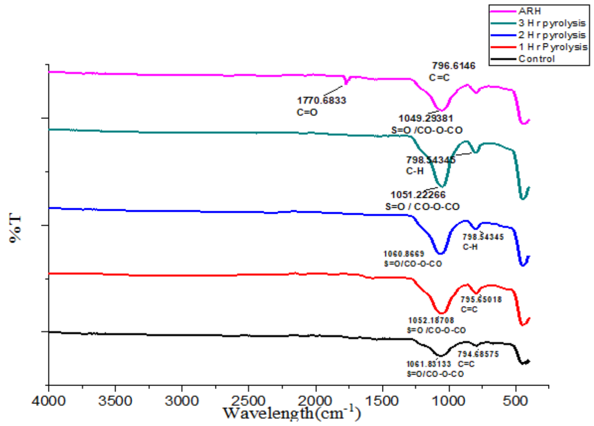

Fig. 11. FTIR of ARH, Raw pyrolyzed RH at different time interval and commercially available Activated Carbon (CAC)

Isotherms: Freundlich, Langmuir, and Redlich Peterson isotherms were plotted (Fig. 12, 13, 14). The constants required for these isotherms were deduced by finding the intercept and slope of the respective graphs, which are given in table 2. The equilibrium adsorption data of oil on the ARH AEW mixture were analyzed by the Langmuir, Freundlich, and Redlich - Peterson isotherm models. The equilibrium adsorption data of oil on the ARH AEW mixture were analyzed by Langmuir, Freundlich, and Redlich - Peterson isotherm models. The isotherm which fitted the experimental data the best is the Freundlich isotherm model. The monolayer adsorption capacity (q_{max}) was 428 mg/g. Pseudo-first-order, pseudo- second-order, and intraparticle diffusion models were used to evaluate the kinetic data. The model which fitted the experimental data the best is Pseudo-first-order kinetic model [37]. It is concluded that the experimental data follows Langmuir Isotherm as its "r^2" value (0.93) is the highest of the three models. The other two models that are used also fits the experimental data, but its fit is relatively lower than that of Freundlich Isotherm.

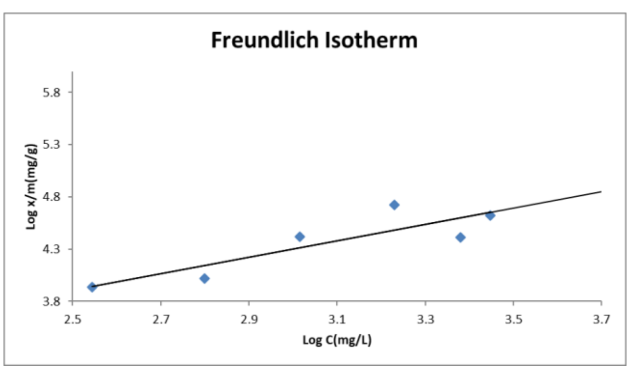

Fig. 12. Freundlich adsorption isotherm of ARH and AEW adsorbent mixture

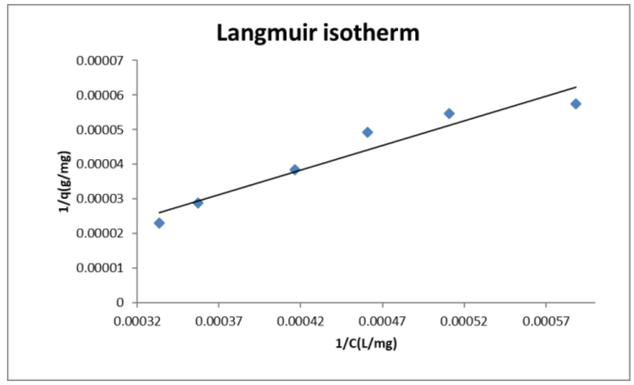

Fig. 13. Langmuir adsorption isotherm of ARH and AEW adsorbent mixture

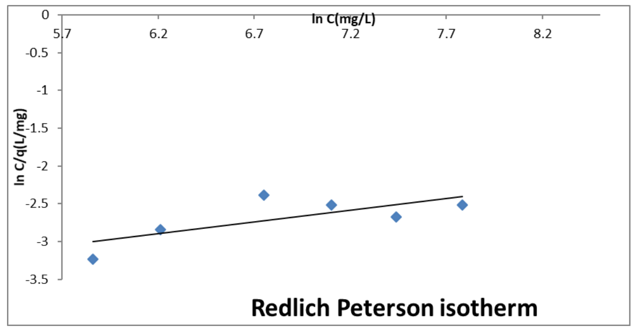

Fig. 14. Redlich Peterson adsorption isotherm of ARH and AEW adsorbent mixture

4. Discussion

This study elucidates the use of ARH and AEW adsorbent mixture and it is evident that this adsorbent is an efficient adsorbent. When compared to other materials that involve oil adsorption, the adsorbent used in this study is practical and advantageous. When compared to the electro spun matrix used by Wu. *et al.* 2012 which adsorbs 110g per gram of adsorbent, ARH – AEW mixture adsorbs only 4.6 g of oil per gram of adsorbent [40]. But the adsorbent used in this study could be easily procured compared to that of making the fiber. Also, the polystyrene that is used to manufacture the matrix could contaminate the water bodies as its monomers, namely, Benzene and Styrene are carcinogenic and neurotoxin [44]. Usage of natural adsorbents was also compared. Raw corncobs studied by Lin *et al*. 2015 adsorb 2.12g of oil per gram of adsorbent [20]. Loofah studied by Diwakar.S *et al.*, 2017 adsorbs 2.588g of oil per gram of adsorbent [9]. Deposited carbon and powdered activated carbon adsorb 2g oil and 3.1g oil per gram of adsorbent which is reported by Okiel *et al*. 2011 [22]. Whereas, ARH – AEW adsorbent mixture adsorbs 4.6g of oil per gram of adsorbent which shows that ARH-AEW adsorbent adsorbs more than the natural adsorbents mentioned previously. There were natural adsorbents that adsorb more oil than that of ARH – AEW adsorbent like Sugarcane Bagasse adsorbed more oil (10.5g oil per gram adsorbent) but is not

Table 2
Constants for isotherms

Isotherm	K	n	Q	A	B	r^2
Freundlich	0.6689/g	1.276	-	-	-	0.76
Langmuir	17.89L/mg	-	0.428g/g	-	-	0.93
Redlich Peterson	-	-	-	1.616mg/L	0.325	0.54

Table 3
Comparison of the adsorbent used in current study with other adsorbents

Citation	Adsorbent used	Gram of oil removed/g adsorbent
Wu. *et.al.* 2012 [40]	Electrospun Polystyrene	110g
Lin *et.al.* 2015 [20]	Raw Corncobs	2.12g
Diwakar. S *et.al*, 2017 [9]	Loofah	2.588g
Lin *et.al.*, 2008 [8]	Powdered used tyre	2.2g
Ali *et.al.*, 2011 [28]	Sugarcane Bagasse	10.5g
Okiel *et.al.* 2011 [22]	Deposited Carbon	2g
Okiel *et.al.* 2011 [22]	Powdered Activated Carbon	3.1g
This Study	ARH and AEW	4.6g

selective as it adsorbs 8.5g water per gram adsorbent which makes the separation of oil from the matrix difficult [20]. The future prospect of this project is based on its reusability. Lin *et al*., 2015 study on powdered tire is a key to this prospect [8]. Although powdered tire could adsorb only 2.2g of oil per gram of adsorbent, its efficiency of reusability in each cycle does not change significantly. If ARH-AEW adsorbent also exhibits such a character, its credibility as an adsorbent would be very high.

5. Conclusion

It is concluded that ARH and AEW mixture is an efficient oil adsorbent, and the addition of activated e-waste results in an increase in yield of oil adsorption. Through this application, value is added to the waste as food and electronics usage in the world would certainly increase in the future and the raw adsorbents would be generated in greater amount in the future. Thus, the waste generated could be used in adsorbing oil spills. As Further studies could be done on the field of reusability and recoverability of oil from the adsorbent to make current study more practical in situ and make it a viable option in treatment of oil spills in a larger realistic case.

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