

Application of activated recycled rubber from used tyres in oil spill clean up

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Abstract

The majority of the inhabitants of the Niger Delta area of Nigeria suffer from environmental pollution caused by frequent oil spillages. The feasibility of using activated recycled rubber from used tyres in oil spill cleanup was investigated. Recycled rubber was activated through carbonization and acid treatment. The activated rubber particles of surface area ranging from 615 to 784 m²/g were used for the absorption studies at temperature between 5 and 40 °C. The results show that as the carbonization temperature increased from 500 to 750 °C the rubber particle surface area increased from 615 to 784 m²/g. Moreover, the equilibrium oil absorption decreased from 8.89 to 5.90 as the temperature of absorption increased from 5 to 40 °C for 615 m²/g, and as the particle surface area increased from 615 to 784 m²/g the equilibrium oil absorption increased from 8.89 to 14.73 for 5 °C. The activation of recycled rubber particles increased the oil absorptive capacity by 1.6 to 2.6 times.

Key Words: Activated rubber particles, crude oil, equilibrium oil absorption, surface area, Niger Delta area

1. Introduction

The occupation of most people living in the Niger Delta includes fisheries, subsistence agriculture, and associated processing industries. The Niger Delta area has suffered for many years from oil spills on land and water. According to Aisien et al. (2003) about 3500 oil spills were reported in Nigeria between 1976 and 1995, with a loss of over 3 million barrels of oil. Recently, as a result of increased bombing or sabotage mostly by militants in the Niger Delta area of Nigeria, an estimated 7 to 10 million barrels of oil have been spilled both onshore and offshore.

Previously, the oil spills were more due to corrosion of oil pipes, poor maintenance of infrastructure, spills or leaks during processing at refineries, and accidental discharge from tankers or vessels and less due to sabotage, vandalisation of the oil infrastructure, and theft of oil. However, sabotage, vandalisation of the oil infrastructure, and theft of oil are the major present day causes of oil spills in the Niger Delta area of Nigeria

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(Nwilo and Badejo, 2005). The effects of oil spills on land include destruction of crops and damage to soil quality and productivity. In water, oil spills destroy fishing activities and contaminate drinking and domestic water sources. They also affect other organisms that have direct or indirect contact activities with the oil contaminated water (Nelson-Smith, 1979; World Bank, 1995).

It has been reported that spraying of expanded graphite and chalk, burning of oil with wicking agents, disposing of oil with detergent, application of floating barriers or booms, use of polymeric foams and other sorbents, and enhanced biodegradation were some of the methods used for oil spill clean-up (Aisien et al., 2006). The disadvantages of these processes are their high cost, inefficient amount of oil removed, environmental pollution, and health hazards (Kingston, 2002). However, presently sorbents that can be polymers, natural materials, or treated cellulosic materials are used for oil spill clean-up (Adebajo et al., 2003). Furthermore, natural, synthetic, and mineral sorbents have been investigated for oil spill clean-up. The most commonly used commercial sorbents are synthetic sorbents made of polypropylene or polyurethane (Hussein et al., 2008). The natural sorbents that have been used in oil spill clean-up include cotton, bark, barley straw, wool, kapok, and rice straw (Choi and Kwon, 1993; Haussard et al., 2003; Radetic et al., 2003). Polymeric sorbents such as polypropylene and polyurethane that can absorb/adsorb 10-30 times their own weight have been reported (Adebajo et al., 2003). However, the ability to absorb/adsorb oil and water in water contaminated by oil has limited their application. Aisien et al. (2003, 2006) have reported the use of rubber particles from recycled scrap tyres that are completely oleophilic and hydrophobic for oil spill clean-up. Moreover, these materials are not only environmentally friendly, easily recoverable and regenerable, low cost, and fast but also very efficient and effective absorbents for oil spills clean-up that are applicable both onshore and offshore. The problems created by the indiscriminate discarding of used tyres into the environment can be addressed by their channelling into useful oil clean-up processes, thereby reducing to the barest minimum the menace associated with their accumulation in the environment. Aisien et al. (2003) earlier reported that the rubber particles from scrap tyres can be used to absorb over 5 times their weight of oil. The present study centres on whether the process of recycled rubber particles activation will enhance its absorption efficiency for the clean-up of oil pollution. Hence, the objective of this study was to determine the effects of activation, surface area, and absorption temperature on crude oil absorption.

2. Materials and methods

2.1. Material collection

Nigerian crude oil of density 840 kg/m^3 was collected with a clean 10 L plastic container from Warri Refining and Petrochemical Company (WRPC), Ekpan – Warri. Scrap tyres were obtained from Imuetinyan Obazee scrap tyre dumpsite in Benin, Nigeria.

2.2. Rubber preparation and activation

The tyre was washed and dried to make it clean. The side of the tyre, free from steel "threads", was cut into sections with a hacksaw into small pieces 2-4 cm long. These tyre chips were then transferred into clean and dried ceramic crucibles and placed in the centre of a furnace for carbonization. The temperature of carbonization was varied from 500 to 750 °C and the activation process was conducted for 2 h at 1 atmospheric pressure. After cooling it was activated with 50% by weight phosphoric acid (Laine et al., 1989). The surface area was

measured using a BET surface analyzer (ASAP 2000 model). Rubber particles of different surface areas were kept in separate plastic containers prior to the oil absorption test.

2.3. Oil absorption studies

Seven 1-L beakers were used for the absorption test. Each of the 7 beakers contained 20 cm³ of crude oil and 100 cm³ of tap water. Ten grams of a given particular surface area was weighed into each of the beakers using a Mettler PM 4800 Delta – range balance. After 5 min, the contents of the first beaker were sieved, until no further drops of oil were observed. Then the new weight of the recycled rubber sample was determined. For the remaining 6 beakers, the same procedure was repeated at successive 10 min intervals until there was no further change in weight. The difference between the weight and the initial weight of each sample in each beaker was regarded as the weight of crude oil absorbed at a particular time. The same procedure was applied to the other 6 beakers containing 20 cm³ crude oil and 100 cm³ water.

For isotherm studies, each beaker contained a crude oil rubber sample, an ice block/ice chip, and a thermometer. The ice was used to maintain the absorption temperatures between 5 and 20 °C, and the water bath was used to achieve the 30 and 40 °C absorption temperatures.

3. Results and discussion

As previously reported, the mass of crude oil absorbed is expressed as the ratio of the mass of crude oil retained to that of recycled rubber (Aisien et al., 2003).

3.1. Effect of rubber particle surface area

Figure 1 shows the variation in rubber particles surface area with the temperature of activation. As the activation temperature increased from 500 to 750 °C the surface area of the activated rubber particles increased linearly from 615 to 784 m²/g with a regression coefficient, R^2 , of 0.9843. These results confirmed those earlier reported by Chang (1996).

The typical effect of rubber particles surface area on crude oil absorption at 5 °C is shown in Figure 2. The results show that as the rubber particles surface area increased from 615 to 784 m²/g the equilibrium absorption of oil increased from 8.89 to 14.78 at 5 °C. The results compared favourably with that reported by Hussein et al. (2009) that sorbent absorption capacity increased with particle surface area. The reason for this is that the uptake of crude oil is a sorption process (absorption and adsorption), which depends on the surface area of contact between the oil and rubber particles. Therefore, the larger the surface area is, the more oil is absorbed. Aisien et al. (2003), Tavisto et al. (2003), Gerald et al. (2003), and Wu and Zhou (2009) reported similar profiles of crude oil absorption using rubber particles, in which there was a rapid initial increase in absorption, followed by a decrease until an asymptotic value was reached at equilibrium absorption. This profile for absorption of crude oil is obviously due to oil concentration difference acting as the driving force. The difference between the concentration of crude oil in the rubber particles initially and that at equilibrium is high. This subsequently decreases to zero at equilibrium absorption of oil (Aisien et al., 2003). Comparison of these results with those earlier reported by Aisien et al. (2003) using the best absorption rubber particle size of 0.150 mm at 5 °C revealed that activation of recycled rubber particles increased the oil absorption by 1.6 to 2.6 times. Therefore, activation of rubber particles gave higher crude oil absorption capacity that compares

favourably with other materials such as waste – wool fibre, acrylate – nitrile – alcohol polymer, polypropylene, cellulose acetate, and CF3 – functionalized silica aerogel earlier reported (Adebajo et al., 2003). This is as a result of the fact that the process of activation increases the specific surface area and hence the absorption capacity of the activated rubber particles increased. This is supported by the report that non-activated carbon has a lower surface area accessible for different adsorbates, whereas the physical and chemical activation are associated with an increase in total pore volume and specific surface area (San, 2002).

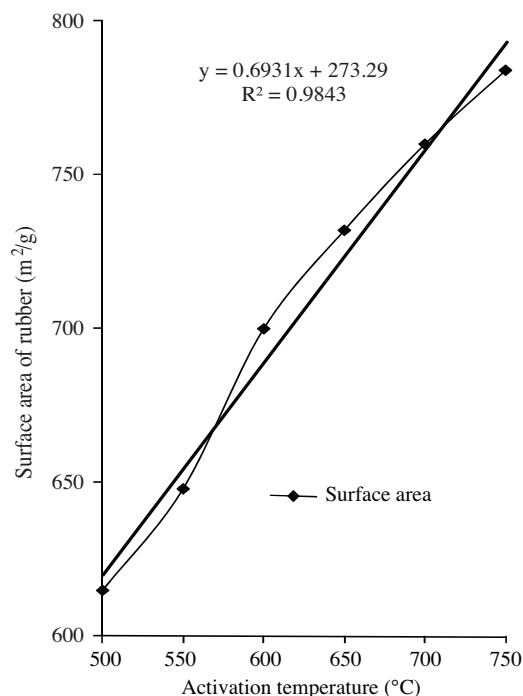


Figure 1. Variation in surface area of rubber with temperature of activation.

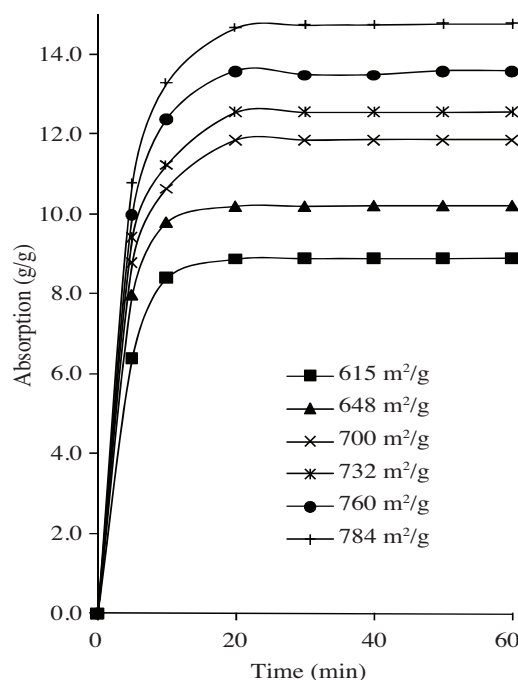


Figure 2. Variation in absorption with rubber particle size and time at 5 °C (278 K).

Figures 3 and 4 also show the typical effect of rubber particles surface area on crude oil absorption at 5 and 30 °C, respectively. The oil absorption profiles are similar to that of Figure 1 and the equilibrium oil absorption varies with temperature. Figure 6 summaries the effect of surface area on equilibrium oil absorption for the different absorption temperatures. The profile observed was opposite to that previously reported by Aisien et al. (2003), that is, the lower the surface area of absorption is, the lower absorption level is at equilibria. However, these results compared favourably with that reported by Aisien et al. (2003) because of the good correlation between rubber particle size and rubber surface area.

3.2. Effect of absorption temperature

The effect of temperature on crude oil absorption using activated rubber particles can be seen by comparing Figures 2-4. The results also reveal that as absorption temperature was increased from 5 to 40 °C the equilibrium oil absorption decreased from 8.89 to 5.90 and from 14.78 to 10.63 for 615 and 784 m²/g surface areas, respectively. The same behaviour was observed for all other particle surface areas. This trend is similar to that earlier reported by Aisien et al. (2003). According to the researchers, these results are typical of sorption

processes, in which the higher kinetic energy of the oil at higher temperature makes retention or adsorption of oil by the rubber particle more difficult.

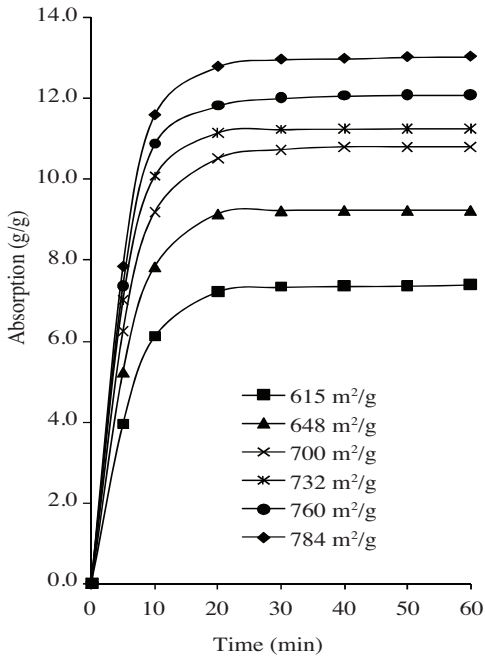


Figure 3. Variation in absorption with rubber particle size and time at 15 °C (288 K).

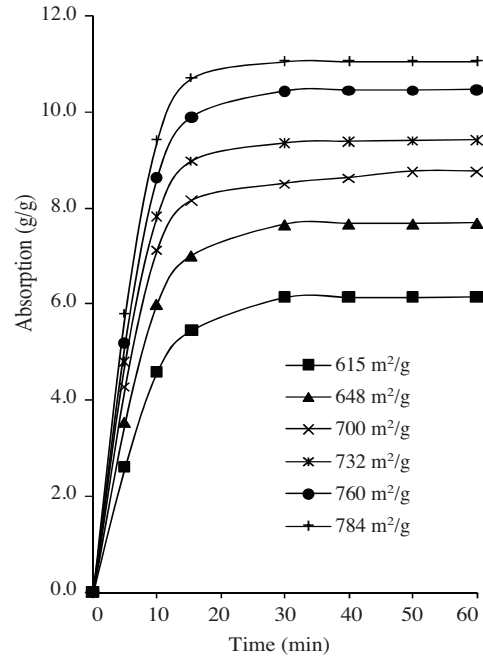


Figure 4. Variation in absorption with rubber particle size and time at 30 °C (303 K).

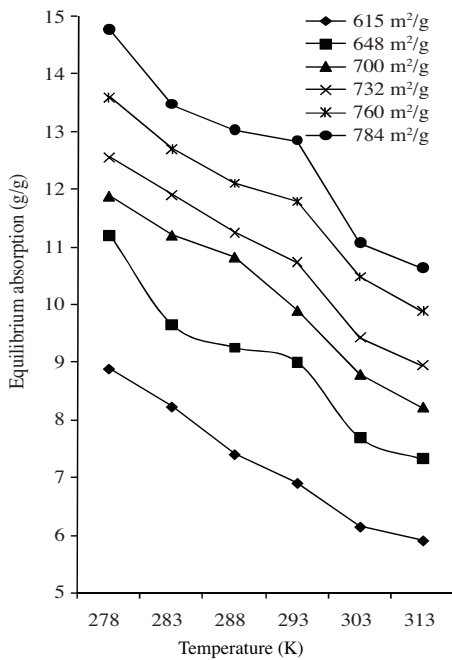


Figure 5. Variation in equilibrium absorption with temperature.

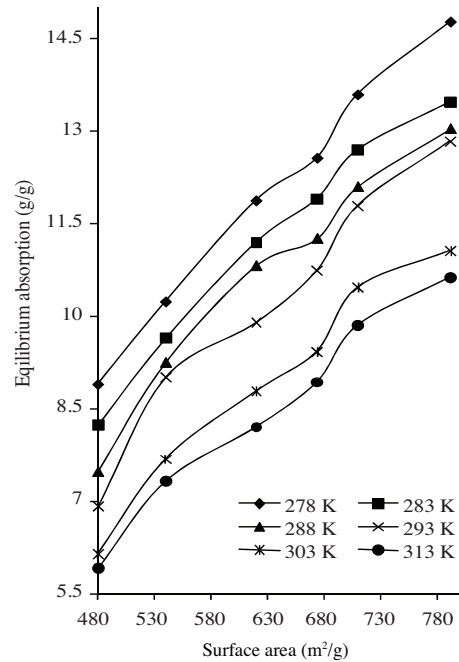


Figure 6. Variation in equilibrium absorption with rubber surface area.

A summary of the effect of temperature on equilibrium oil absorption for the different rubber particle surface areas is shown in Figure 5. The variation is in accordance with the pattern observed so far, that is, the lower the temperature of absorption is, the higher is the level of absorption at equilibria. However, these results do not compare favourably with that of Hussein et al. (2009), whose report states that the oil sorption capacity increases with increasing temperature. This might be as a result of the fact that they used cellulosic material compared with polymeric material (rubber) used in our study.

4. Conclusions

The carbonization and activation of recycled rubber from scrap tyres resulted in rubber particles of different and higher surface areas.

Activated rubber particles exhibit higher oil removal efficiency when compared with the non-activated rubber particles.

Increase in activation temperature increases the rubber particle surface area.

As the particle surface area increased from 615 to 784 m²/g, the equilibrium oil absorption increased from 8.89 to 14.73 for 5 °C absorption temperature.

The equilibrium oil absorption decreased from 8.89 to 5.90 as the temperature of absorption increased from 5 to 40 °C for 615 m²/g.

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