

Sequestration Of Carbon (IV) Oxide By Adsorption Using Activated Carbon Prepared From Oil Palm Shell And Oil Palm Fiber

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Abstract—The sequestration of CO₂ from exhaust gas using oil palm shell (OPS) and oil palm fiber (OPF) as potential raw materials for the preparation of activated carbon was investigated. Chemical activation using phosphoric acid (H₃PO₄) was employed for the preparation of activated carbon. The functional group in the activated carbon was determined using Fourier Infrared Spectrometer. The effects of various factors namely contact time, adsorbent dosage, and adsorbent particle size was studied to identify the adsorption capacity of oil palm shell (OPS) and oil palm fiber (OPF). The FTIR spectra of the activated carbon indicated the presence of hydroxyl, phenols, carboxyl, carbonyl, lactones, pyrones, and anhydride groups. The percentage of CO₂ adsorbed was found to be dependent on adsorbent dosage, contact time and particle size. The highest amount of CO₂ captured within the range of parameters studied was >50%. The adsorption process showed that both precursors were effective in the capturing of CO₂ from the exhaust gas.

Keywords—Sequestration, CO₂, activated carbon, adsorption, oil palm shell, oil palm fiber.

1. Introduction

Carbon (IV) oxide is a focus of attention as one of the greenhouse gases (GHG) which cause global warming. The early implementation of effective measures to prevent global warming is strongly desired. One conceivable measure for preventing global-scale warming is separation and capture of the CO₂ contained in flue gas discharged into the atmosphere from thermal power plants, steel works, factories, and other facilities in the course of industrial activity, followed by fixation and effective utilization [1].

Various methods for separation and capture of CO₂ from flue gas have been proposed, including chemical absorption using an amine solution,

physical adsorption using an adsorbent, and membrane separation methods, among others [1,2]. However, in order to realize practical application of these technologies, the cost of CO₂ separation and capture must be substantially reduced, as this account for a large part of the total cost of carbon (IV) oxide capture and storage (CCS). Among the different technologies under development for CO₂ capture, the adsorption technology using activated carbon looks promising due to the inherently low energy consumption [3].

Activated carbon adsorption has attracted more attention in recent time by many scientists. But commercially available activated carbons are still expensive [4,5,6]. As a result of this, researchers have shifted attention to the use of cheaper alternatives, which are relatively inexpensive, and equally endowed with reasonable adsorptive capacity.

This work was carried out to study the sequestration of CO₂ using activated carbon prepared from oil palm shell and oil palm fiber.

2. METHODS

2.1 Pre-treatment of raw materials

The raw materials were washed several times with de-ionized water to remove all traces of impurities, dirt, oil, dust etc. and dried in the sun for about 72hours to remove excess water. The washed and dried raw materials were grounded into fine particles using grinding machine and be sieved into different particle sizes.

2.2 Production of activated carbon

2.2.1 Acid Impregnation

The acid impregnation of the raw material was done using the method described by [7]. 100g each of the raw materials were impregnated with concentrated ortho-phosphoric acid at different ratios of acid to raw material 1:1 on the weight basis. The impregnated samples were dried in a Memmert oven at 120°C for 24hours.

2.2.2 Carbonization of raw materials

The method described by Nwabanne and Igboke [7] was used. The dried samples were carbonized in a muffle furnace for 2 hours at 500°C. The carbonized samples were cooled to ambient temperature and weighed to determine the yield of activated carbon from the materials. The samples were washed with de-ionized water several times until pH 6-7 is obtained. They were then filtered with Whatman No.1 filter paper and dried in the oven at 110°C for 8 hours. The dried samples were pulverized, passed through different sieve sizes and were stored in air tight bottle ready for use.

2.3 Characterization of activated carbon

2.3.1 Determination of pH of activated carbon

The pH of the carbon samples were determined using standard test of ASTM D 3838-80 [8].

2.3.2 Determination of moisture content of the raw materials and activated carbon

Moisture contents of the samples were determined using ASTM D 2867-91 [9].

2.3.3 Determination of ash content

The ash contents were determined using a standard method according to ASTM D 2866- 94 [8].

2.3.4 Determination of bulk density of activated carbon

The bulk densities of the activated carbon were determined according to the tamping procedure by Ahmedna et al [10].

2.3.5: Determination of iodine number of activated carbon

The iodine number was determined based on on ASTM D 4607-86 [11] by using the sodium thiosulphate volumetric method.

2.3.6 Determination of volatile content of raw materials and activated carbon

1.0g each of sample was weighed and placed in a partially closed crucible of known weight. It was heated in a muffle furnace at 900°C for 10min.

2.3.7 Determination of percentage fixed carbon

This is the solid residue other than the ash resulting from the volatile matter test. The value was obtained from the difference from 100% of the sum of moisture content, volatile matter and ash content. The percentage fixed carbon is given by:

$$100 - (\text{Moisture content} + \text{ash content} + \text{volatile matter}) \% \quad (1)$$

2.3.8 Determination of surface area

The specific surface area of the activated carbon was estimated using Sear's method [12,13] by agitating 1.5g of the activated carbon samples in 100ml of diluted hydrochloric acid at a pH = 3.

2.3.9 Fourier transform infrared (FTIR) spectrometer

FTIR spectroscopy was used to identify the chemical groups present in activated carbon. The samples were examined using spectrophotometer with range 400-4000cm⁻¹. KBr was used as background material in the analysis. FTIR spectra were recorded using FTIR spectrophotometer.

2.4 Adsorption process for CO₂ capturing experimental procedure

The source of CO₂ was the exhaust-pipe of petrol/diesel generator. The petrol generator was on and allowed to stand for 5 minutes. A gas analyzer was connected to the exhaust pipe of the petrol generator for 10minutes to determine the compositions of the exhaust gas before adsorption. 10g of activated carbon was packed in a glass tube affixed to the exhaust pipe of the petrol generator and a gas analyzer was connected to determine the composition of the exit exhaust gas from the glass tube. The percentage of CO₂ adsorbed was calculated using equations 2. The procedure was repeated using different adsorbents, contact time, particles sizes and adsorbent dosage.

$$\% \text{ Adsorbed} = \frac{[(C_o - C_e)]}{C_o} \times 100 \quad (2)$$

Where, C_o and C_e are the composition of CO₂ in the air (%) at initial and any time t, respectively.

3. Results and Discussion

3.1 Yield of activated carbon

The yield of activated carbons was calculated from sample weight after activation to its initial weight. It is seen that yield of activated carbon of 35.50 and 37.21 were recorded for OPF and OPS respectively at activation temperature of 500°C, activation time of 1 hour and acid impregnation ratio of 1.0. From Figure 1, it could be observed that OPS yielded more activated carbon.

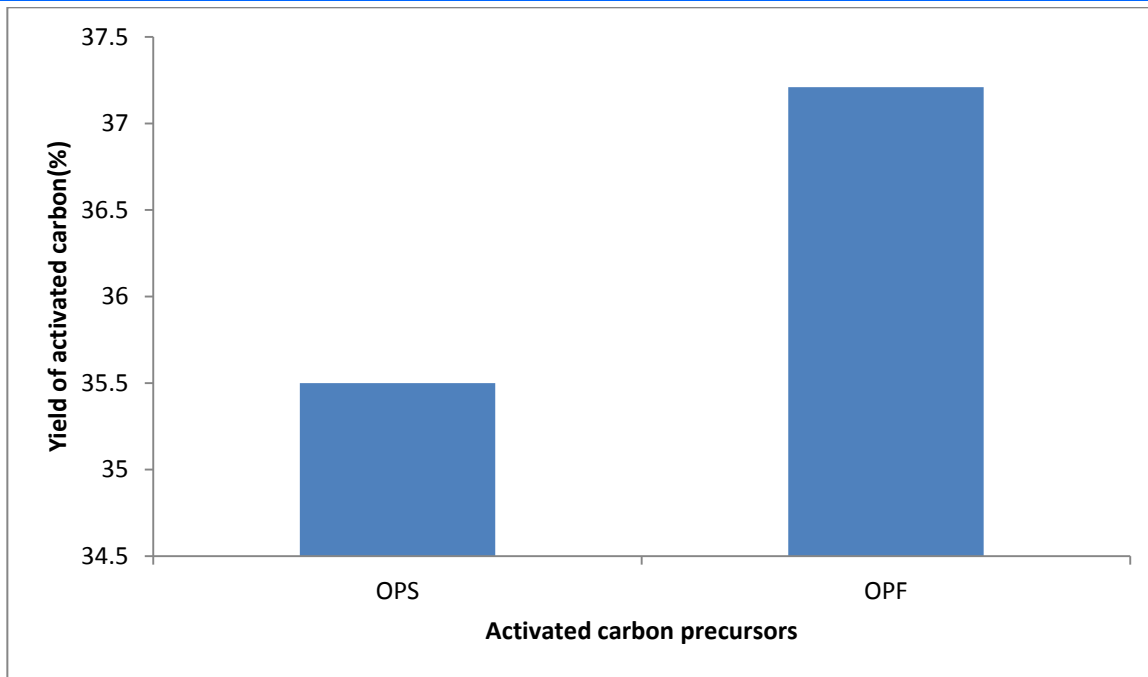


Figure 1: Yield of activated carbon with different precursors.

3.2 Characteristics of activated carbon derived from palmyra palm nut:

The physico-chemical characteristics of activated carbon are shown in Table 1.

Table 1: Physico-chemical characteristics of activated carbon derived from palmyra palm nut.

Properties	Values	
	OPS	OPF
Volatile matter (%)	17.20	24.20
Ash content (%)	2.92	5.20
Fixed carbon (%)	74.30	68.00
pH	6.80	6.70
Moisture content (%)	1.90	3.60
Surface area (m ² /g)	859.73	720.51
Iodine number (mg/g)	815.10	680.10
Bulk density (g/cm ³)	0.70	0.60

3.3 Fourier transform infrared spectrometer (FTIR)

The adsorption capacity of activated carbon depends upon porosity as well as the chemical reactivity of functional groups at the surface [14]. Knowledge of surface functional groups gives insight to the adsorption capability of the produced activated carbon. FTIR spectroscopy was used to identify the chemical groups present in the activated carbon.

The FTIR spectra of the produced activated carbon were shown in Figures 2 and 3. FTIR spectra of the activated carbon indicated the presence of hydroxyl, phenols, carboxyl, carbonyl, lactones, pyrones, and anhydride groups as shown in Table 2. These are important sorption sites [15]. For all the active carbons, the maximum peak was 3852.04cm⁻¹ while the minimum peak was 578.76cm⁻¹.

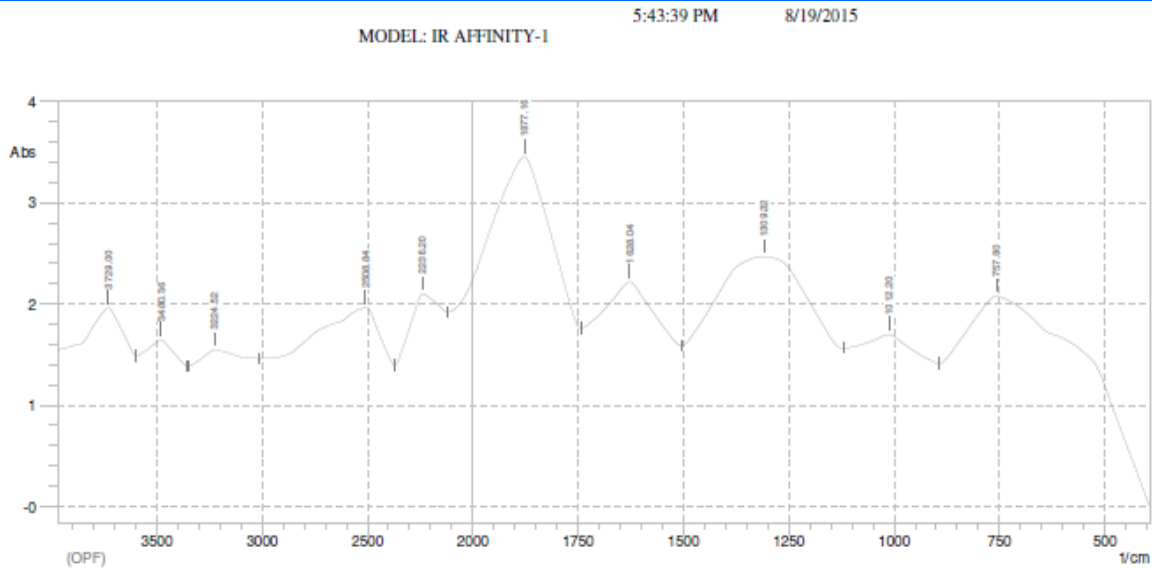


Figure 2: FTIR spectrum for activated carbon from OPF.

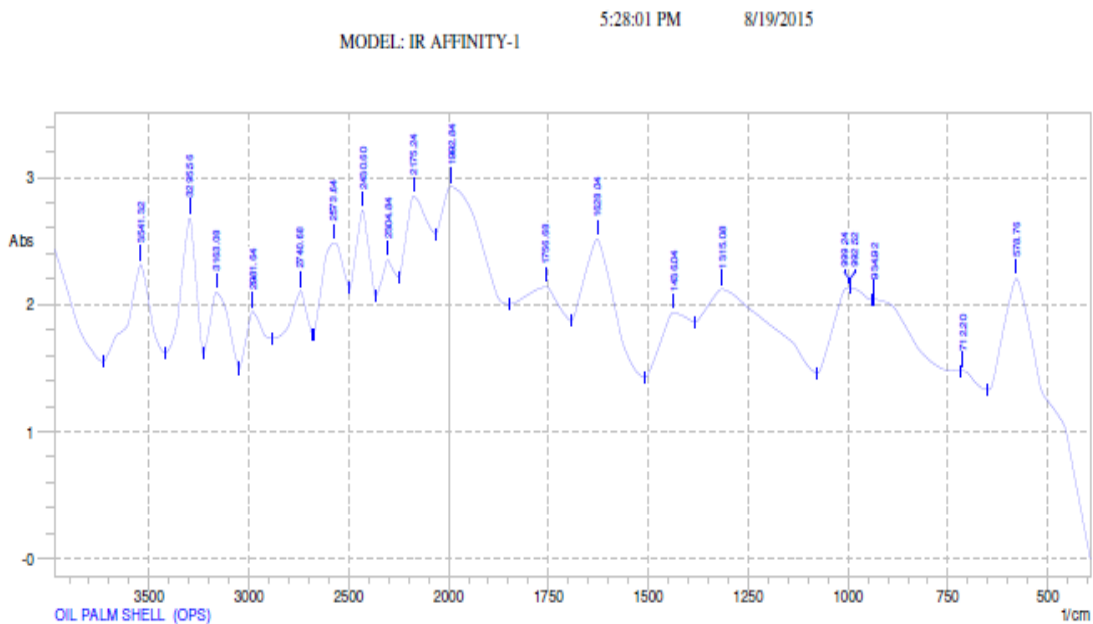


Figure 3: FTIR spectrum for activated carbon from OPS.

Table 2: Fourier Transform Infrared Spectrum for activated carbon produced from OPS and OPF.

OPS wave number (cm ⁻¹)	OPF wave number (cm ⁻¹)	Bond source
3541.32	3729	O-H stretch of phenol
3163.08-3295.56	3480.36-3224.52	O-H stretching mode hydroxyl groups N-H stretch
2175.24-2981.64	2236.2-2508.84	C≡C stretch of alkyne
1628.04-1992.84	1628.04-1877.16	Quinonic and carboxylate groups N-H bending, C=O stretch
1315.08	1012.2	CH ₂ and CH ₂ bend pyrones and aromatic groups
1436.04	1309.32	C – O stretch vibration of esters, ethers, anhydride, alcohol, carboxyl amide, C-C stretch.
934.92-999.24	757.8	C-H stretch, N-H rocking
712.2	757.8	N-H rocking, C-H rocking, C-Cl ₂ , C-Br.
578.76		C-I aromatic ring deformation vibrations

3.4 Adsorption Process

3.4.1 Effect of particle size on the adsorption process

The adsorption capacity of activated carbon increases with decreases with particle size. The removal of CO₂ at different particle sizes showed that the removal rate increased better with a decrease in particle size (Figure 3). The relatively higher adsorption with smaller adsorbate particle may be

attributed to the fact that smaller particle yield large surface area. There is a tendency that a smaller particle produces shorter time to equilibrium. According to Weber and Morris [16], the breaking of larger particles tends to open tiny cracks and channels on the particle surface of the material resulting in more accessibility to better diffusion, owing to the smaller particle size.

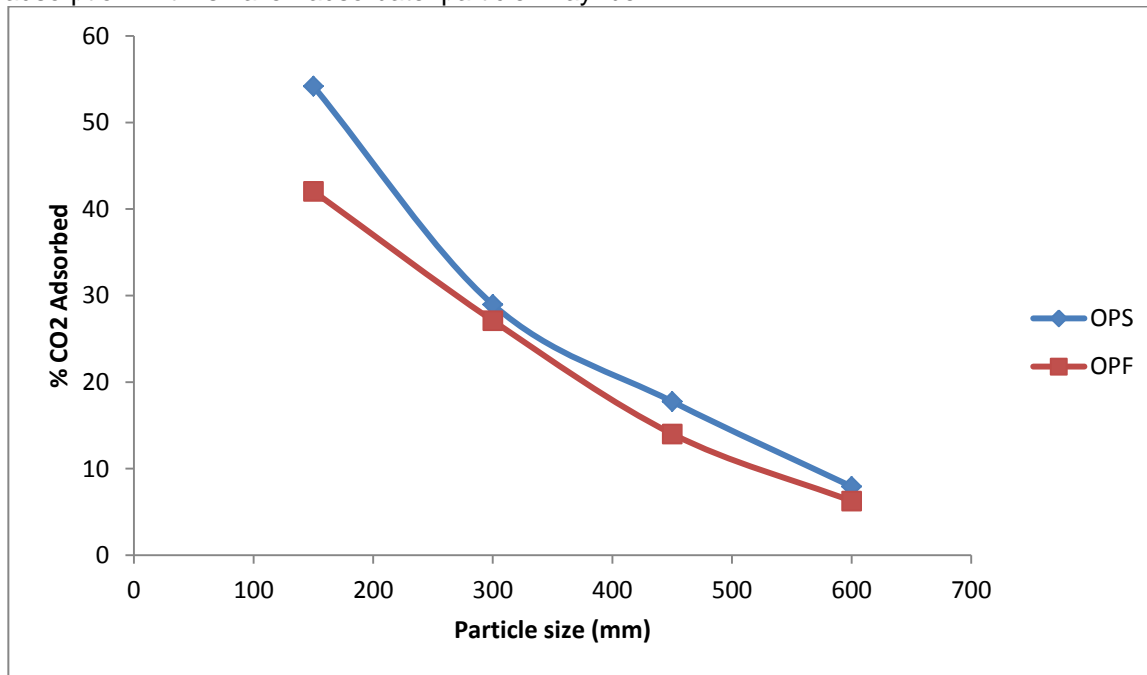


Figure 2: CO₂ adsorption with different particle sizes of different adsorbents at conditions of adsorbent dosage 30g and time of 30mins.

3.4.2 Effect of contact time on the adsorption process.

The results of percentage CO₂ adsorbed are presented in Figure 3. It was found that the CO₂ adsorption percentage increased with increasing contact time. Above 30% of CO₂ adsorption occurred in the first 15 to 30mins and thereafter the rate of adsorption of the adsorbate species into the adsorbent was found to be slow. The time required to reach equilibrium on CO₂ adsorption was 30mins.

The initial rapid adsorption is could be due to the availability of the large surface area of the adsorbents for adsorption. The later slow adsorption is probably due to the surface area of the activated carbons been filled up and the slow pore diffusion of the solute CO₂ into the bulk of the adsorbent [17]. In addition, Li et al., [18] suggest that the rapid adsorption at the beginning of the process is due to external surface of the adsorbent, and is followed by slower internal diffusion process.

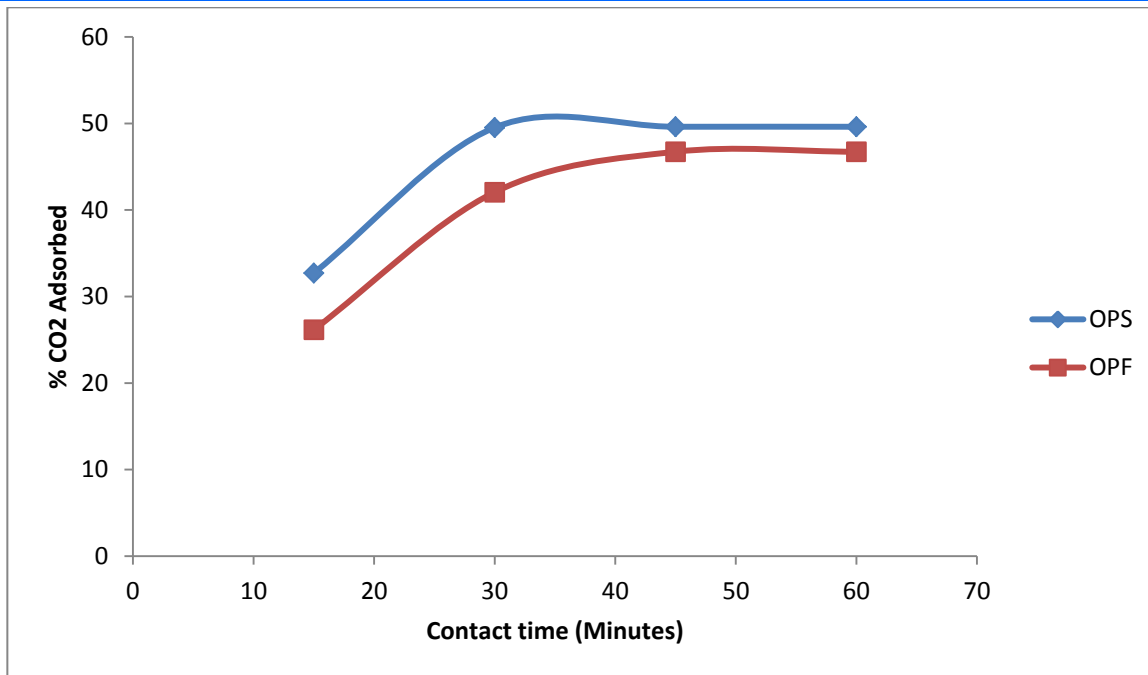


Figure 3: CO₂ adsorption at different time of different adsorbents at conditions of adsorbent dosage 30g and particle size of 150mm.

3.4.3 Effect of adsorption dosage on the adsorption process

Adsorption dosage is an important parameter because this factor determines the capacity of an adsorbent for a given initial concentration of the adsorbate. The results showed that as the adsorbent dosage increased, the percentage of adsorption also increased but the amount of CO₂ adsorbed per unit mass of the adsorbent decreased considerably

(Figure 4). The decrease in unit adsorption with increasing dose of adsorbent is basically due to adsorption sites remaining unsaturated during the adsorption reaction [19].

Figure 4 reveals a definite increase in the adsorption capacity of the adsorbents with dosage. This is due to the larger number of available adsorption sites favouring the enhanced uptake of the amount of solute absorbed per unit mass of adsorbent [14;7].

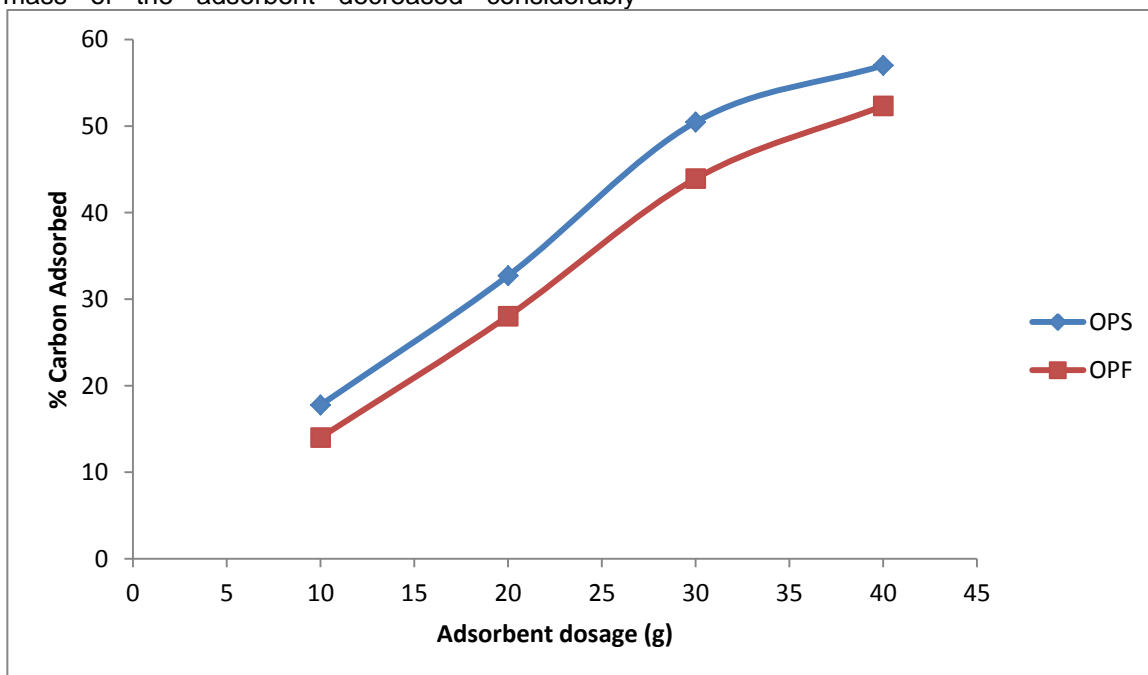


Figure 4: CO₂ adsorption at different adsorbent dosage of different adsorbents at conditions of adsorption time 30mins and particle size of 150mm.

4. CONCLUSION

The sequestration of CO₂ from exhaust gas of a generator set using activated carbon prepared from oil palm shell and oil palm fiber has been investigated in this work. The adsorption processes showed that activated carbon from the both precursors were effective in the capturing of CO₂ from the exhaust gas. The amount of CO₂ adsorbed was found to vary with particle size, contact time and adsorbent dosage. The highest amount of CO₂ captured within the range of parameters studied was >50%.

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