



# SULPHUR DIOXIDE REDUCTION ON COCONUT-SHELL BASED ACTIVATED CARBON BY PHOSPHORIC ACID IN A WET PACKED BED SCRUBBER

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## Abstract

In the current study, a laboratory scale wet packed bed scrubber was used for the reduction of SO<sub>2</sub>. A coconut-shell based activated carbon was prepared by 2M phosphoric acid and obtained 56.8% yield and used as a packing material consisting 0.70 – 0.84 mm (20-25 mesh). The SO<sub>2</sub> gas was supplied to an activated carbon-packed bed column for a range of residence times (15, 30, 45, and 60 minutes) at a range of temperatures (303K, 313K, 323K and 333K). The results demonstrate that 303 K is more efficient in reducing SO<sub>2</sub> (88%) for 60 minutes. The characterization of coconut-shell based activated carbon was studied.

**Key words:** Sulphur dioxide (SO<sub>2</sub>), wet packed bed scrubber, coconut-shell based activated carbon (CSAC).

## 1. Introduction

Sulphur dioxide (SO<sub>2</sub>) is a harmful gas that significantly contributes to acidification, the formation of photochemical smog as well as other environmental and health hazards [1]. Chemical oxidation of sulphur (SO<sub>2</sub>) exhaled during the combustion of fossil fuels generates sulfuric acid (H<sub>2</sub>SO<sub>4</sub>), a major precursor of new airborne particles with well-recognized negative impacts on human health, the environment, and the climate. Methanesulfonic acid (MSA), which is formed concurrently with SO<sub>2</sub> during the atmospheric oxidation of organosulfur compounds (OSCs), such as dimethyl sulphide, is another precursor. Acid rain may result from atmospheric sulphur dioxide (SO<sub>2</sub>). Coal-fired power station exhaust gas streams are indeed the primary source of SO<sub>2</sub>. There are many commercially available methods for removing SO<sub>2</sub> from flue gas (flue gas desulfurization, or FGD), including scrubbing, adsorption, absorption, and catalytic reduction [2, 3].

To remove SO<sub>2</sub> in flue gases, a multitude of adsorbents have been employed such as activated carbon, zeolites, and metal oxides including CuO and Al<sub>2</sub>O<sub>3</sub> supported MgO. There are primarily two restrictions on this kind of emissions management which is 1) becoming saturated with the adsorbate, the adsorbent materials occasionally need to be regenerated before being used again. Renewal may also be energy-intensive and result in the loss

of certain adsorbent materials, which might start reducing the capacity during adsorption, 2) Although these materials, which are primarily supplied in pellet form, possess a relatively greater BET area, the method is often restricted in its ability to fully use the active sites of adsorption, resulting in an abrupt breakthrough curve. [4,5].

Among the various treatment processes scrubbing methods plays major role which are classified as wet based FGD, dry based FGD and semi-dry based FGD. These methods involve solvents including limestone, calcium hydroxide and magnesium hydroxide slurries, sodium hydroxide solutions, and other organic solvents are utilised in these procedures as absorbent. The most popular methods for desulfurizing flue gases rely mostly on scrubbing with limestone slurries acting as an absorbent. The residue from these no regenerative processes is either turned into gypsum or dumped in a landfill [6,7].

On an industrial scale, activated carbon (AC) is widely applied as an adsorbent, primarily in the purification and separation of gases and liquids, and as a catalyst and catalyst support. There are two existing methods for preparation of activated carbon which is chemical and physical treatment method is the phenomenon of activation which occurs in the presence of activating substances that either exists in a solid or liquid condition. On a variety of raw materials, dehydrating agents such as KOH, NaOH, H<sub>3</sub>PO<sub>4</sub>, ZnCl<sub>2</sub>, Na<sub>3</sub>PO<sub>4</sub>, NaCl, as well as KMnO<sub>4</sub> were processed to make activated carbon of a commendable grade. Because of their superior dehydrating properties among the many dehydrate reagents; zncl2 and phosphoric acid are often used in commercial manufacturing. Due to the depolymerization, dehydration, and redistribution of biopolymers in lignocellulosic materials, H<sub>3</sub>PO<sub>4</sub> is utilised as an activating agent in the current investigation [8,9,15,19].

In this work, the coconut-shell based activated carbon were prepared and packed in the column. The wet packed bed scrubber was used to reduce the concentration of SO<sub>2</sub> in the presence of H<sub>2</sub>O. The effects of parameters like temperature and time were investigated.

## 2. Experimental Section

### 2.1 Materials

Coconut-shell collected from local market, phosphoric acid with 99% purity and high purity (>99.9%) SO<sub>2</sub> was injected in commercial cylinders.

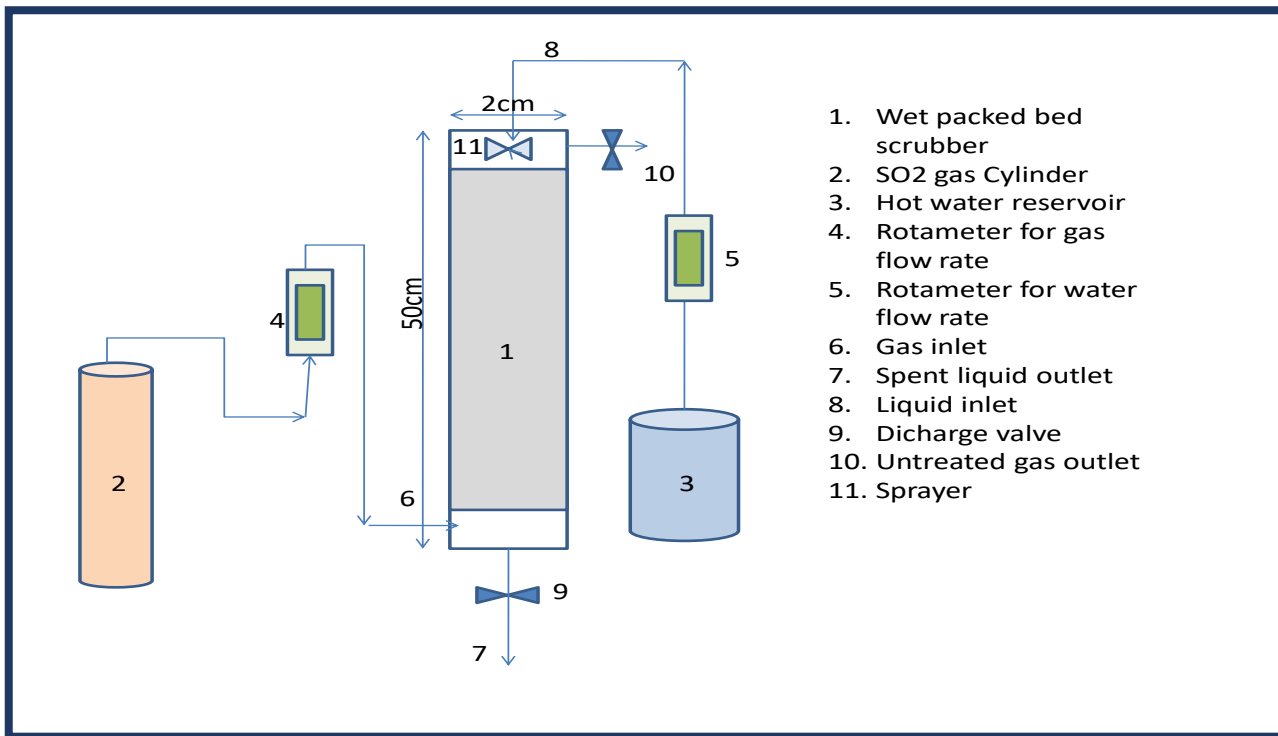
### 2.2 Apparatus and Procedure

A wet packed-bed scrubber column consisting of a 2 cm internal diameter by 50 cm long quartz tube as shown in Fig1. The porous quartz frit placed at the bottom and top of the column to support activated carbon derived from coconut shells that with 0.70 to 0.84 mm (20-25 mesh) [17,20]. With a flow rate of 50 ml/min, 2000 ppm of SO<sub>2</sub> gas was supplied at the bottom of the column, and the extra gas was collected at the top. At the top of the scrubbing column, a sprayer with a 3mm nozzle diameter was employed to disperse hot water at a rate of 100 ml per minute. Rotameter was utilized to regulate the flow rates of both SO<sub>2</sub> and hot water. The experiment was repeated with different resident times and temperatures (15, 30, 45, and 60 minutes) (303K, 313K, 323K and 333K). As SO<sub>2</sub> and H<sub>2</sub>O reacted, H<sub>2</sub>SO<sub>4</sub> was generated, which was collected at the bottom, and the absorbed SO<sub>2</sub> concentration was estimated using the NaOH titration method. Equation 1 was applied to define the function of the packed bed column in respect of SO<sub>2</sub> removal efficiency.

$$\text{so}_2\text{reduction efficiency, } \eta = \frac{(\text{so}_2)_{\text{in}} - (\text{so}_2)_{\text{out}}}{(\text{so}_2)_{\text{in}}} \times 100 \quad \dots\dots\dots (1)$$

Where,  $(SO_2)_{in}$  is the  $SO_2$  inlet concentration and  $(SO_2)_{out}$  is the  $SO_2$  outlet concentration[10].

**Fig. 1: Wet Packed bed Scrubber set-up**



## 2.3 Preparation of Coconut-Shell based activated carbon

A coconut shell was washed, dried in hot air for 6 hours at 105°C, then crushed (0.5-1cm). 100g of dried coconut shell was impregnated with 400ml of 2M phosphoric acid, and indeed the mixture was left at room temperature for 24 hours. In order to begin the carbonization process, the mixture was transferred to a mud pot, sealed, and heated at 450°C for 3 hours at a rate of 10°C/min, then cooled until it reached room temperature. The product obtained was dried in an oven at 105°C after being rinsed with distilled water until the neutral pH whereas 56.8 g of activated carbon was obtained. Finally, the product was crushed and sieved in particle size between 0.70 to 0.84 mm (20-25 mesh)[11,12]. A schematic diagram of coconut-shell based activated carbon as shown in fig 2.

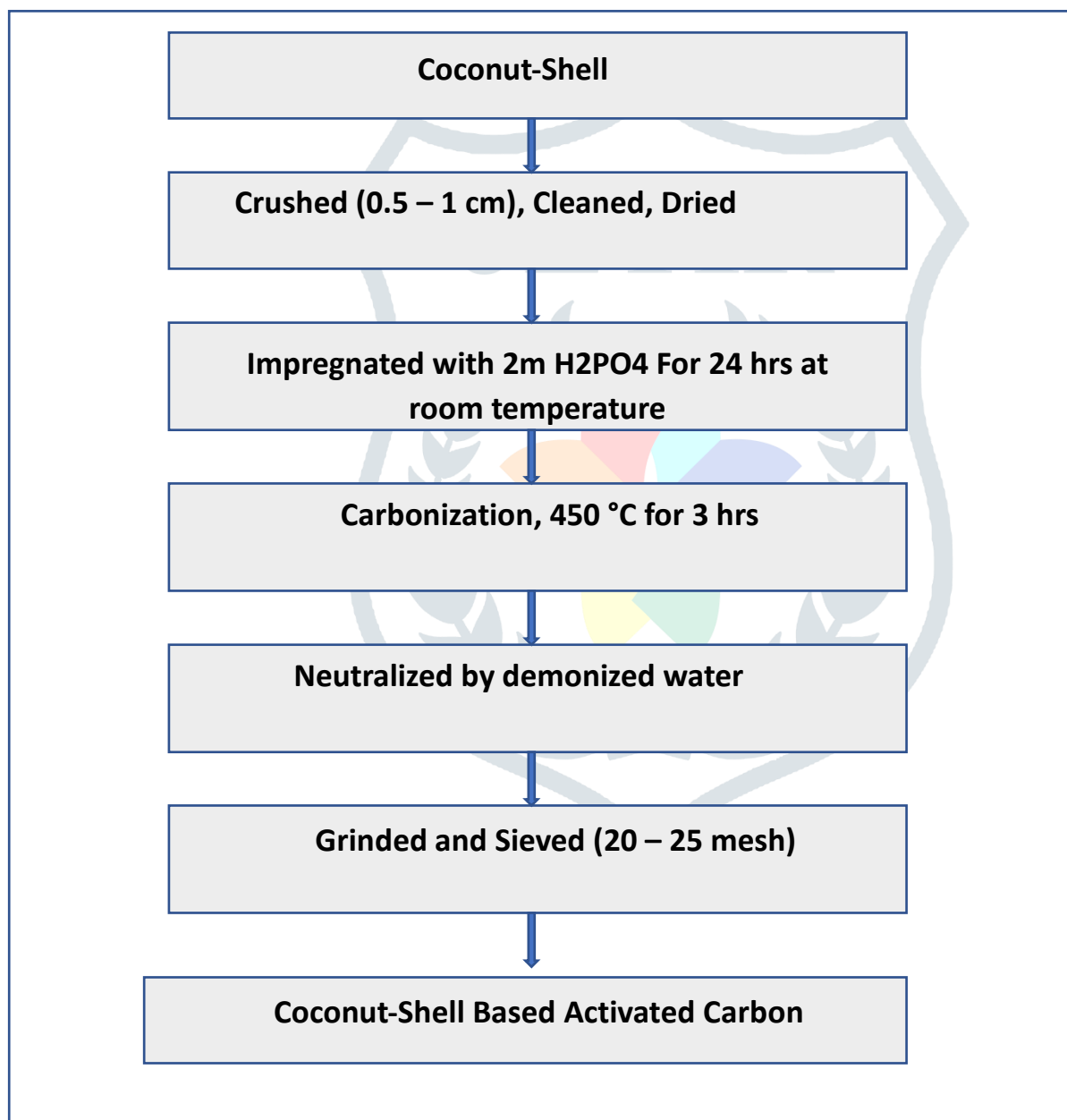


Fig 2: A schematic diagram of coconut-shell based activated carbon

## 2.4 Characterization methods and procedures for activated carbon

### 2.4.1 Iodine number

The milligrams of iodine absorbed by 1 g of carbon at a residual filtrate iodine concentration of 0.02 N is known as the iodine number. Iodine number is a widely used metric for testing activated carbon due to its simple

and offers a rapid evaluation of the quality of the material. It provides an estimate of the porosity and surface area.

A dry sample of activated carbon was weighed, then 10 ml of 5% HCl acid was added, and the solution was blended until the sample was moistened. The mixture was then heated for 30 seconds, and then cooled. The mixture was then added 100 ml of standardised iodine solution, which was then agitated for 30 min until being filtered. A standardised 0.1 N sodium thiosulfate solution was used to titrate 50 ml of the filtrate in the presence of starch as an indicator[10, 11].

$$\text{Iodine number} = \frac{X}{m} \times A$$

$$X = (N_1 \times 100 - N_2 \times V \times \left(\frac{110}{50}\right)) \times 126.93$$

Where, m is the weight of activated Carbon in grams, X is the weight of adsorbed iodine in mg, and A is the correction factor established after determining the residual filtrate normality.

#### 2.4.2 Methylene Blue Number

It represents the amount of mesopore in activated carbon and is measured in milligrams of Methylene blue adsorbed per grams of carbon. Methylene blue was used for this work due to its well-known potent adsorption onto solids and its proven utility in defining adsorptive material. The molecular weight of methylene blue is  $373.9 \times 10^{-3} \text{ kg mol}^{-1}$ [12].

#### 2.4.3 Methyl Violet Number

The methyl violet test is similar to the methylene blue test in that it indicates the available surface area, which is the adsorption capacity of the activated carbon[12].

#### 2.4.4 Moisture content (MC)

As per ASTM Standard E1756-08, 1g of sample was placed in a silica crucible with a lid in a muffle furnace at  $105 \pm 3^\circ\text{C}$  for 3 hours, but no longer than 72 hours, as well as weighed after cooling[13,14].

#### 2.4.5 Ash content (AC)

As per ASTM Standard E1755-01, 1 g of dried sample was burned in a silica crucible with lid in a muffle furnace at  $575 \pm 25^\circ\text{C}$  for 3 hours[13,14].

#### 2.4.6 Volatile matter (VM)

As per ASTM Standard E872-82, 1 g of dried sample was burned in a silica crucible with lid in a muffle furnace at at  $950^\circ\text{C}$  and heated for 7 minutes[13,14].

#### 2.4.7 Fixed carbon content (FCC)

It was estimated by subtracting the percentages of volatile matter and ash content from 100%[13,14].

$$\text{FCC} = 1 - \text{MC} - \text{ASH} - \text{VM} \quad (2)$$

**Table 1: Characterization of Coconut-shell based activated carbon**

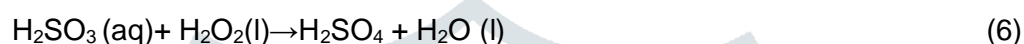
Parameters	Coconut-Shell based activated carbon
Iodine number (mg/g)	995
Methylene Blue Number (mg/g)	56.8
Methyl Violet Number (mg/g)	71.2
Moisture content (%)	9.2

Ash content (%)	12.4
Volatile matter (%)	19.8
Fixed carbon (%)	58.6

### 3. Results and discussion

#### 3.1 Effect of Coconut-Shell based activated carbon on SO<sub>2</sub> reduction mechanism

SO<sub>2</sub> was adsorbed on coconut-shell based activated carbon (CSAC), after the SO<sub>2</sub> contacted with the activated carbons in the presence of H<sub>2</sub>O, it forms H<sub>2</sub>SO<sub>3</sub>[15]. The aqueous H<sub>2</sub>SO<sub>3</sub> was mixed with H<sub>2</sub>O<sub>2</sub> to form H<sub>2</sub>SO<sub>4</sub>. Activated carbon would reduce SO<sub>2</sub> using the following chemical change:



#### 3.2 Effect of various residence time and temperature on SO<sub>2</sub> reduction efficiency

The experiment employed varied resident times, comprising 15 minutes, 30 minutes, 45 minutes, and 60 minutes, as well as different temperatures, comprising 303 K, 313 K, 323 K and 333 K independently. That illustrates while resident time rises, SO<sub>2</sub> reduction also rises, however SO<sub>2</sub> reduction reduces as temperature rises. 303 K temperature with 60min residence time provides higher yield compare with other[16,17]. Fig. 3 shows the effect of resident time and temperature on SO<sub>2</sub> reduction efficiency.

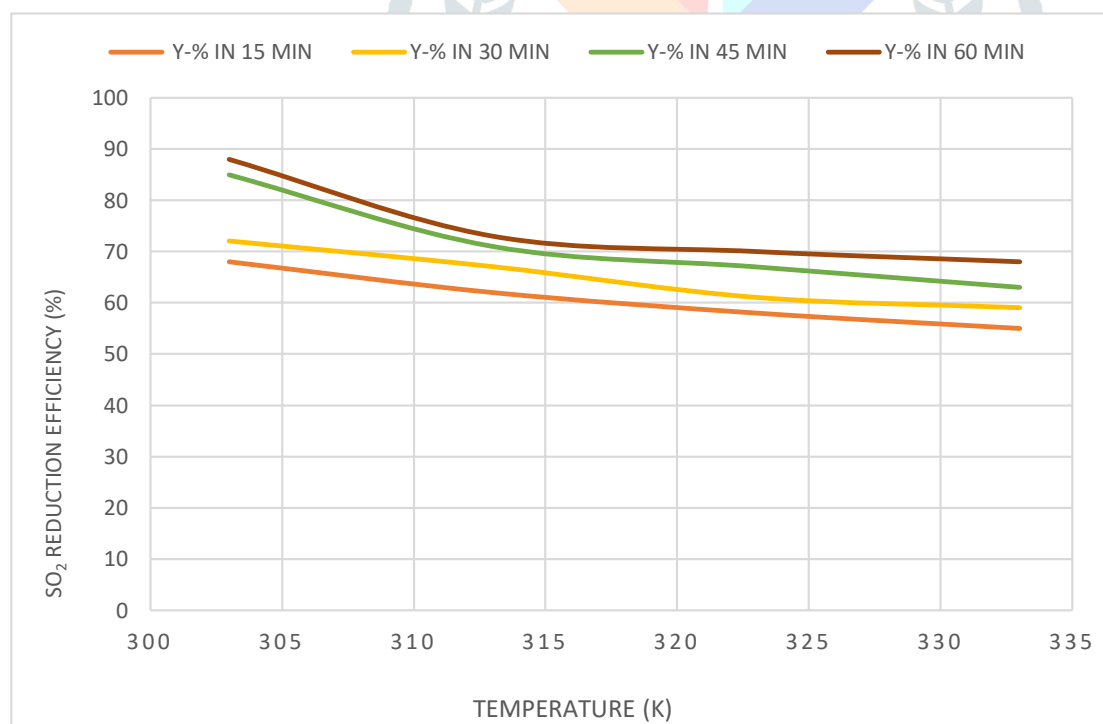


Fig 3 Effect of resident time and temperature on SO<sub>2</sub> reduction efficiency

#### 3.3 Effect of Coconut-Shell based activated carbon

In table 1, the synthesized activated carbon has more micropores and less mesopores, as revealed by the iodine number of 995 mg/g, which is significantly higher than the methylene blue number of 56.8 mg/g and the methyl violet number of 71.2 mg/g [12]. Mostly a good activated carbon are expected to have iodine values

equal to or higher than 900 mg/. The CSAC provides higher surface area for mass transfer between SO<sub>2</sub> and H<sub>2</sub>O. Proximate analysis like moisture content, ash content, volatile matter and fixed carbon content were analyzed [13,18].

#### 4. CONCLUSION

A wet packed scrubber was used to reduce the SO<sub>2</sub> concentration. A coconut-shell based activated carbon was prepared by 2M phosphoric acid which was used as a packing material. The effect of temperature and residence time were investigated that shows maximum residence time with minimum temperature is feasible for more reduction of SO<sub>2</sub>[20]. The mechanism between SO<sub>2</sub> and H<sub>2</sub>O on CSAC was studied. The characterization of coconut-shell based activated carbon like proximate analysis, iodine number, methylene blue number and methyl violet number were analysed that implies CSAC has more micropores and less mesopores[19,20].

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