# Salinity Removal from Drinking Water Using Chemically Modified Wood Waste Activated Carbon

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**Abstract.** Salinity in drinking water poses significant health risks and challenges for water sustainability. Although there are varieties of water treatment technologies are available, low cost, and efficient alternative of water treatment is always appreciable. This study explores the effectiveness of various adsorbents in removing salt ions from saline water. Wood waste being a source of natural biodegradable cellulosic fiber content has a potentiality to produce activated carbon under proper condition. Twenty samples from three selective wood waste have been produced using same activating agent at different activation temperature, activation period and these activated carbon samples were systematically analyzed to optimize removal efficiency in both batch and column adsorption at different rpm of analyzer, dosing of adsorbent, contact time of adsorbent and initial chloride concentration of water. It has been found that Swetenia Mehagony impregnated with $H_3PO_4$ acid (1:1) ratio at 900℃ activation temperature for 2 hour has shown the best result of removal efficiency of 56.56%. Another finding is that Gmelina Arboreaare and Acacia Auriculiformis impregnated with $H_3PO_4$ (1:1) at 800˚C activation temperature and for 2hr activation period shows the maximum removal efficiency of 47.64 % and 48.58% respectively. The controlling factor that affects the removal efficiency also analyzed such as adsorbent dosing rate was 4g/l, best rpm of the batch analyzer was found 120, initial concentration 500mg/l was more efficient and ideal adsorbent contact time was 180min. The results of equilibrium adsorption investigations have been fitted into various adsorption models including Langmuir and Freundlich.

**Keywords:** *Salinity, wood waste, activated carbon.*

## 1 Introduction

The Drinking water salinity is becoming a greater issue not only in the Asian coastal region of Bangladesh, China, and Vietnam but also in California, Brazil, the Netherlands and other place [1]. Exposure to high level of salinity via drinking water leads to hypertension, high blood pressure, cardio vascular diseases (CVD), strokes, pre-eclampsia during pregnancy, infant mortality etc.[2]. For the treatment of the saline water


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reverse osmosis, Electrodialysis and Electrodialysis reversal, Ion Exchange Technology, and Thermal Technology are all conventional desalination techniques being developed worldwide [3]. These available technologies for saline water treatment are expensive and unavailable for rural people. In comparison with these techniques, adsorption process is cost-effective [4]. Activated carbon has been established as an excellent adsorbent material because of its large surface area, improved porosity, and high surface reactivity [5]. Carbon materials with high porosity and high surface area are termed activated carbons which are manufactured from coal, lignocellulosic materials, synthetic materials etc. Agricultural residues, forestry by-products, sewage sludge, etc. are a few examples of lignocellulosic precursors for activated carbon production. Wood waste is an ample natural biodegradable fiber that is rich in cellulosic fiber content. In general, processing of 1,000 kg of wood in the furniture industries will lead to waste generation of almost half (45 %), i. e., 450 kg of wood [6]. Similarly, when processing 1,000 kg of wood in sawmill, the waste will amount to more than half (52 %), i. e., 520 kg of wood [7]. Three selective trees wood waste such as *Swietenia Mahagony*, *Acacia Auriculiformis* and *Gmelina Arboreaare* investigated for producing chemically modified activated carbon and its application in the treatment of water for removal salinity.

Aiming to obtain new carbonaceous materials with specific structural and morphological characteristics from renewable sources, the present work proposes to investigate the preparation of activated carbon by chemical activation with phosphoric acid ($H_3PO_4$) of wood waste followed by hydrothermal activation at different temperature and then base leaching with potassium hydro-oxide (KOH) and its application in the batch adsorption studies of salinity removal (chloride ion) at different dosing, rpm, contact time and the best chemically activated carbon sample and its kinetics modelling are presented through concentration versus removal efficiency.

## 2 Methodology

Fig.1, describes the total process flow diagram and Fig. 2, is a salinity meter used in the laboratory to get the result of final and initial salinity of sample water and to calculate removal efficiency. The salinity removal efficiency and carbon yield percentage are calculated using equation (1) and (2) respectively.

$$Removal\ Efficiency = (final\ salinity - initial\ salinity) / initial\ salinity \times 100 \quad (1)$$

$$Carbon\ yield\ (\%) = (Mass\ of\ activated\ carbon \div Mass\ of\ dried\ wood\ waste) \times 100 \quad (2)$$

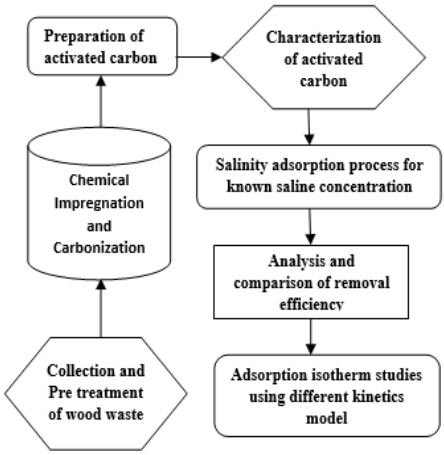


**Fig. 1.** Process flow diagram.

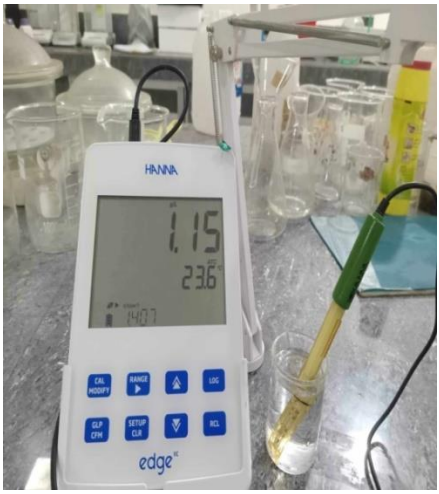


**Fig. 2.** Salinity measurement.

## 2.1 Raw Materials collection

Three selective wood waste like Swetenia Mehagony, Acacia Auriculiformis and Gmelina Arbora were collected from furniture shop nearby the Shahjalal University of Science and Technology, Sylhet, Bangladesh. These wood wastes were cut into 2cm ×2cm pieces, washed with distil water 3 to 4 times, oven dried and preserved for the next procedure.

### 2.2 Impregnation With $H_3PO_4$ Acid for Activation

To impregnate the wood waste, 1M 20% $H_3PO_4$ was used in (1:1) ratio with the sample. The impregnation was carried out at 70 $^0$C in a thermostatic water bath for all the samples until excess water evaporates. The impregnated samples are then oven-dried at 120 $^0$C for 24 hrs [8].

### 2.3 Carbonization of Impregnated Wood Waste

The carbonization is carried out at five different temperatures (600-1000) $^0$C and at three different time period (1-3) hr. The impregnated wood waste samples were inserted into stainless steel tubular reactor having 6 inches in length and 2 inches in diameter by providing an inert environment and then placed into a muffle furnace for a specific time and temperature.

### 2.4 Base leaching with 1M KOH

After activating the samples, the resulting activated carbons needed to be washed to lower the ash content and to remove the metallic impurities and residual chemicals [9]. For base leaching, the activated carbons were immersed in 1M 20% KOH solution at 40 $^0$C temperature and after the leaching the samples were washed with distil water 3 to 4 times to adjust the pH at 7 and then oven dried the samples at 120 $^0$C for overnight.

### 2.5 Grinding Activated carbon

Samples were grinded into small pieces and sieve through ASTM #30 sieve to achieve a consistent particle size of particle sizes ranging in between 0.4 and 2.5 mm [10].

### 2.6 Synthetic Saline Water Preparation

The saline water is prepared synthetically in the lab as the collected water may contain other ingredients. The required amount of sodium chloride is added to distilled water to obtain saline water of a specified concentration of 900 mg/L.

### 2.7 Adsorption Process

Adsorption is an effective method for the removal of different ions in water treatment. For the removal of salinity, the behavior of activated carbon as adsorbent is studied. As a part of the experimental work on laboratory scale primarily batch adsorption in suspension was continued and then best performed samples were gone through column adsorption in continuous flow.

**Batch Adsorption in Suspension.** The adsorption capacities of 15 types of activated carbons were checked in suspension for dosing of 2 g/L, 4 g/L, 6 g/L and 8 g/L with a

fixed chloride concentration of 900 mg/L. Among them, the top one activated carbon obtained from different carbonization temperature and time have been selected for further analysis and by using the same temperature and time another 5 types of samples were prepared to check variation in the removal efficiencies of these sample. The optimum dosing is selected based on the maximum removal efficiency for a fixed contact time until the concentration reached equilibrium. The contact time is determined based on the removal efficiencies of all the activated carbon samples for different dosing, different concentration until equilibrium is reached.

**Column Adsorption in Continuous Flow.** On experimental basis, the filter media has been established using activated carbon for salinity removal on laboratory scale. Total 12 types of activated carbon containing duplicate samples have been prepared as a part of filter media.

**Salinity Measurement.** The initial and final salinity concentration is measured by using Salinity meter (Edge EC, Model: HI2003-02) in gram/Liter (g/L).

## 3 Results And Discussion

Table.1 shows the selective samples carbon yield analysis and salinity removal efficiency.

**Table 1.** Removal Efficiency of Derived Activated Carbon

| Activated Carbons | Notation | Initial salinity g/l(0 min) | Final salinity g/l (180min) | Removal efficiency % | Carbon yield analysis, % |
|---|---|---|---|---|---|
| *Swetenia Mehagony* with $H_3PO_4$ (1:1) at 800 $^0$C for 2hr | HP-M-8-2 | 2.13 | 0.92 | 56.56 | 60 |
| *Swetenia Mehagony* with $H_3PO_4$ (1:1) at 900 $^0$C for 1hr | HP-M-9-1 | 2.13 | 1.16 | 45.3 | 50 |
| *Acacia Auriculiformis* with $H_3PO_4$ (1:1) at 800 $^0$C for 2hr | HP-A-8-2 | 2.13 | 1.09 | 48.58 | 53.33 |
| *Gmelina Arborea*are with $H_3PO_4$ (1:1) at 800 $^0$C for 2hr | HP-G-8-2 | 2.13 | 1.11 | 47.64 | 51 |

### 3.1 Effect of activation temperature on removal efficiency

Form different activation period (1-3) hr., it is found that for different temperature range (600-1000) $^0$C, for all activated carbon samples at 800 $^0$C shows the best result for salinity removal efficiency. Fig. 3, exhibits the effect of activation temperature on the

removal efficiency of chloride ions for phosphoric acid impregnated Swetenia Mehagony (HP-M) sample in (1:1) ratio at 800 $^0$C showed the best removal efficiency in optimum activation period, revolution per minute, dosing, contact time and fixed initial concentration.

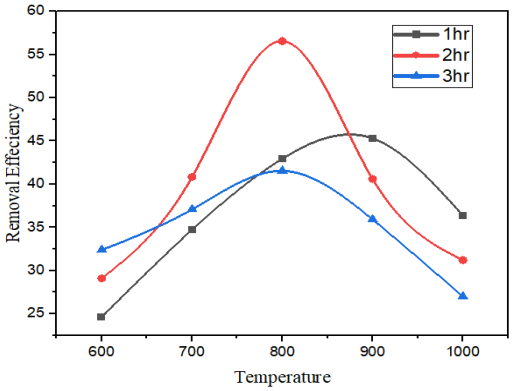


**Fig. 3.** Effect of activation temperature on removal efficiency.

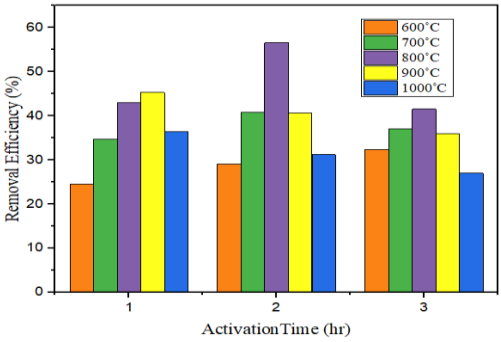


**Fig. 4.** Effect of activation time on removal efficiency

### 3.2 Effect of activation time on removal efficiency

When activation temperature 800 $^0$C is fixed it is found that from different activation period (1-3) hr., for all activated carbon samples 2hr activation period shows the best result for salinity removal efficiency. Fig. 4 exhibits that among all samples Swetenia Mehagony impregnated with $H_3PO_4$ in (1:1) ratio for 2hr activation period showed the best removal efficiency in optimum activation temperature, revolution per minute, dosing, contact time and fixed initial concentration.

### 3.3 Effect of revolution per minute on removal efficiency

For batch adsorption in suspension at fixed dosing of 4g/l and fixed initial concentration of 900mg/l and for a fixed contact time of 20 min, the effect of rpm ranges from (80-

240) in a Flocculometer jar tester performed and rest the solution for 10 minutes it is found that 120rpm is best for the suspension process. Fig. 5, describes the effect of floculator rpm on removal efficiency.

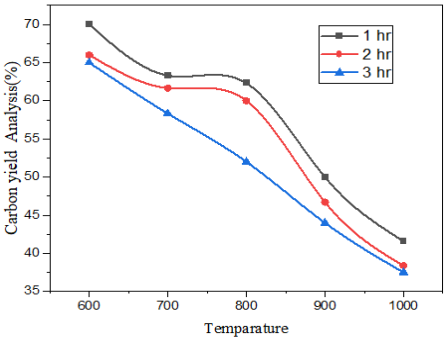


**Fig. 5.** Effect of floculator rpm on removal efficiency

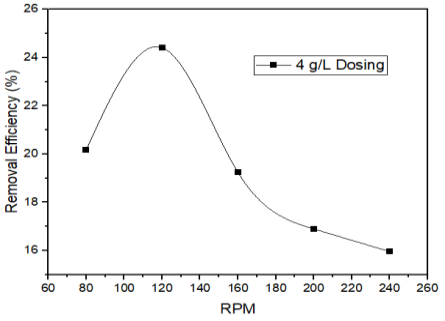


**Fig. 6.** Effect of activation temperature on carbon yield analysis.

### 3.4 Effect of activation temperature on carbon yield analysis

Fig.6, exhibits the effect of activation temperature (600 – 1000) $^0$C on carbon yield analysis for 5 different samples at three different time period and it illustrated that 600 $^0$C temperature and 1hr activation period is best for carbon yield analysis.

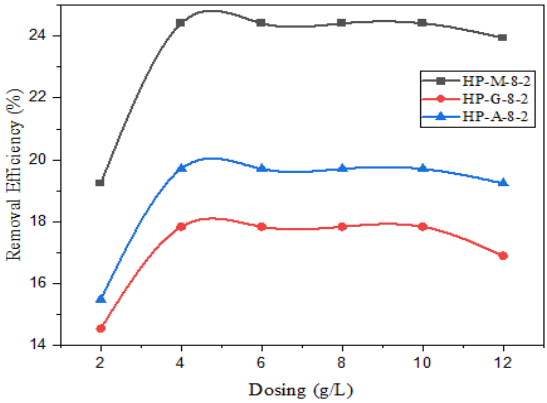


**Fig. 7.** Effect of adsorbent dosing on removal efficiency.

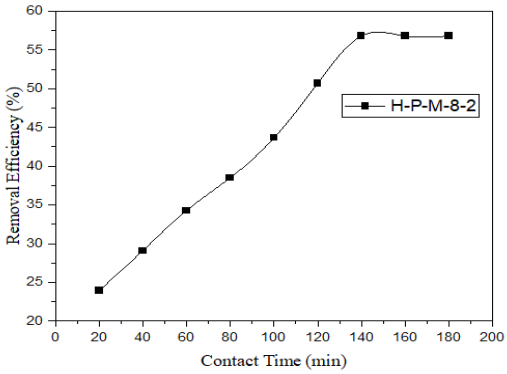


**Fig. 8.** Effect of contact time on removal efficiency.

### 3.5 Effect of different dosing on removal efficiency

For batch adsorption in suspension at fixed revolution per minute 120 and fixed initial concentration of 900mg/l and for a fixed contact time of 20 min, the effect dosing ranges from 2g/l to 12g/l performed in a Flocculator jar tester and rest the solution for 10 minutes it is found that 4g/l is the best for the suspension process. Fig. 7, describes the effect of different adsorbent dosing (2-12) g/l on removal efficiency for three different activated carbon samples.

### 3.6 Effect of contact time on removal efficiency

For batch adsorption in suspension at fixed 120 rpm, dosing 4g/l and fixed initial concentration of 900mg/l and the effect of adsorbent contact time ranges from (20-180) min performed in a Flocculator jar tester and rest the solution for 10 minutes it is found

that (120min- 180min) is the best for salinity removal efficiency. Fig. 8 describes the effect of adsorbent contact time on removal efficiency for (HP-M-8-2) sample and it shows that (140-180) min is best for removal efficiency.

### 3.7 Effect of concentration on removal efficiency

**Table 2.** Removal Efficiency of Activated Carbon at different concentration.

| Notation | Initial salinity, g/l | Final salinity, g/l | Removal efficiency (%) |
|---|---|---|---|
| **HP-M-8-2-A** | 1.23 | 0.51 | 58.53 |
| **HP-M-8-2-B** | 1.45 | 0.62 | 57.24 |
| **HP-M-8-2-C** | 1.55 | 0.66 | 57.41 |
| **HP-M-8-2-D** | 1.82 | 0.79 | 56.59 |
| **HP-M-8-2-E** | 2.13 | 0.92 | 56.80 |

A=500 mg/L, B=600 mg/L, C=700 mg/L, D=800 mg/L, E=900 mg/L

For batch adsorption in suspension at fixed 120 rpm, dosing 4g/l and adsorbent contact time 180 min, the effect of initial concentration ranges from (500-900) mg/l performed in a Flocculator jar tester and rest the solution for 10 minutes, it is found that for initial concentration of 500mg/l shows the best result for salinity removal efficiency.

### 3.8 Adsorption modelling

$$Longmuir\ Isotherm,\ 1/q_e = 1/K_L * 1/C_e + 1/q_{max} \quad (3)$$

Where $q_e$ is the adsorption capacity adsorbed at equilibrium, $q_{max}$ is the maximum adsorption capacity (mg/g), $K_L$ is the Langmuir adsorption constant (L/mg), and $C_e$ is the equilibrium concentration of the adsorbate (mg/l).

**Table 3.** Isotherm parameter for removal of salinity for HP-M-8-2-E

| Types of isotherms | Parameter | HP-M-8-2-E |
|---|---|---|
| Langmuir | $q_{max}$ (mg/g) | 316.4556962 |
| | $K_L$ | 0.000251829 |
| | $R_L$ | 0.613658 |
| | $R^2$ | 0.99839 |
| Freundlich | 1/n | 1.231527094 |
| | $K_f$ | 4.378647661 |
| | $R^2$ | 0.99775 |

$$\text{Freundlich Isoterm},\ Log\ qe = LogK_f + \frac{1}{n} LogCe \quad (4)$$

Where $q_e$ represents the mass adsorbed per unit mass of adsorbent (adsorption capacity), $K_f$ is a constant related to the adsorption capacity, known as the Freundlich coefficient and Ce represents the equilibrium concentration of the adsorbate in solution, $n$ is another constant associated with the intensity of adsorption.

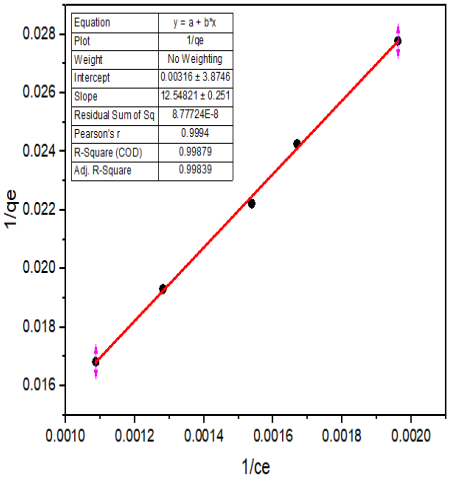


**Fig. 9.** Langmuir Isotherm for HP-M-8-2.

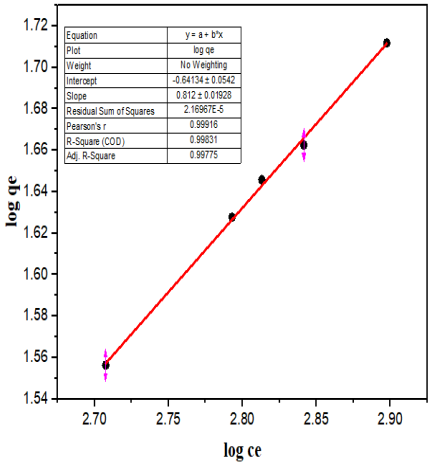


**Fig. 10.** Freundlich Isotherm for HP-M-8-2.

From Fig. 9 and from Table 3 it is shown that for HP-M-8-2 separation factor ($R_L$) is larger than zero but less than one, favoring the adsorption phenomenon. Maximum monolayer coverage capacity for HP-M-8-2 was observed to be 316.45 mg/g. And the value of $R^2$ was 0.9983 proving that sorption data suits the Langmuir Isotherm model well. Hence the sample showed the best adsorption capacity. From figure 10 and from table 3 it is shown that for HP-M-8-2 the constant $K_f$ is a rough measure of adsorption

capacity, whereas 1/n is a function of the strength of adsorption in the adsorption process [11]. When n = 1, the partitioning between the two phases is unaffected by concentration. If the value of 1/n is less than one, the adsorption is normal. Conversely, a value of 1/n greater than one suggests cooperative adsorption [12]. From Table 3, for HP-M-8-2 heterogeneity parameter (1/n) was observed to be 1.231 with the value of $R^2$ being 0.9977. So, for both case the adsorption is cooperative.

## 4 Conclusions

Activated carbon is a great adsorbent and can be used as a cost effective and eco-friendly technology to remove salinity from drinking water. Some important factors such as activation temperature, activation period, activating agent as well as dosing of adsorbent, contact time in suspension, initial concentration etc. have been recognized to have significant impact on the adsorption capacity of activated carbon.

1. Among twenty types of activated carbon produced in this experimental work, *Swetenia Mehagony* impregnated with $H_3PO_4$ acid (1:1) ratio at 800 $^0$C for 2hours is found to be best adsorbent in terms of salinity removal and its maximum salinity removal efficiency is 56.56%
2. Among five different temperatures 800 $^0$C is found to be best for activation and among three different time period 2 hour is found to be the best activation period for maximum salinity removal.
3. Among six different dosing of adsorbent 4g/l is found to be best for salinity removal so adsorbent – adsorbate ratio is (1: 250) which is followed for every experiment. Again 120rpm, 180min contact time of adsorbent and 500mg/l initial concentration is found to be the best for maximum salinity removal.

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