SUITABILITY OF GRANULAR AND POWDERED ACTIVATED CARBON AS AN ADSORBENT FOR DESALINATION

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INTRODUCTION

The world demand for drinking water has significantly increased since the world's population has tripled in the twentieth century – which is expected to increase by another 40% - 50% by 2050. Drinking water scarcity is a major problem in the world. As an Island surrounded by the Indian Ocean, there is ample opportunity to purify sea water in Sri Lanka. Towards the latter part of the monsoon rains in Sri Lanka-: dry zones face acute problems with regard to the lack of drinking and domestic water. When comparing to the world - although Sri Lanka is rich in drinking water, the people in the dry zone travel hundreds of miles to fill one pot of water during the dry season in the year.

According to the previous studies, many Arabian countries have used sea water purification using activated carbon clothes, carbon nano tubes, solar energy etc. However, these methods are very expensive despites the residuals which leads to environmental impacts. Therefore this study is an environmentally friendly, cost-effective easy method to remove NaCl in sea water. Different low-cost adsorption methods were employed, using various activated carbon sources such as coconut shell, bamboo, saw dust of Jak tree trunk and watermelon peel. High adsorption capacity, low cost, high availability and being environmentally friendly are the major reasons to choose these four media for this study

Objectives

The main goal is to find a feasible solution to desalinate sea water to be used for drinking purposes as a solution for the water scarcity problem in Sri Lanka.
The specific objectives of the study were,

- To find a low-cost solution in removing salinity of sea water by adsorption isotherm
- To evaluate the salt removal efficiency of different activated carbon filter media.

METHODOLOGY

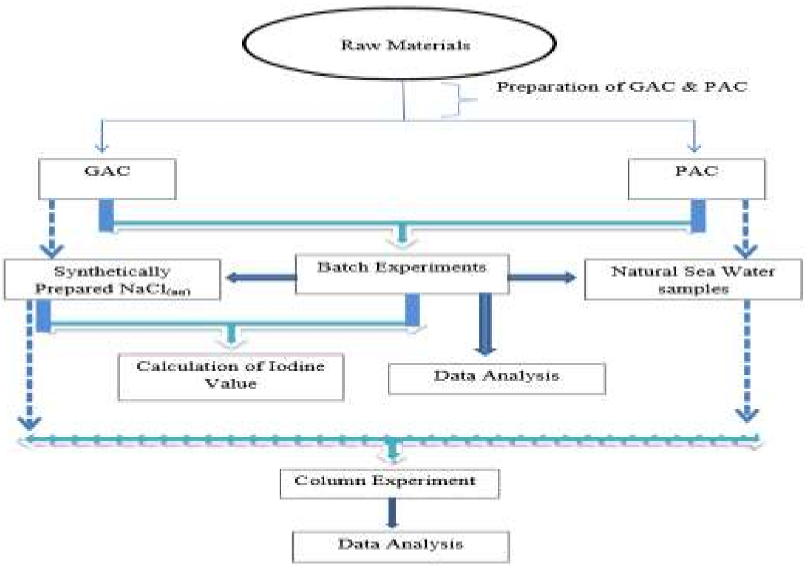


Figure 2.1: Sketch Diagram of the procedure

According to figure 1, the raw materials mentioned above were dried with heat (Up to 600^0C, 700^0C & 800^0C for 3 hours) and sunlight to convert into Activated Carbon (AC). Those AC were sieved in order to get Granular Activated Carbon (GAC) and Powdered Activated Carbon (PAC) using 2mm and 0.2mm sieves. Then Batch experiments were done to the natural sea water samples and synthetically prepared sea water samples varying the weight of AC, volume of water samples, changing the time and angular velocity. Next, Iodine Value (IN) was calculated using GAC. Column experiments were done to different AC medium, using the *Hydrilla verticillata* to find the efficiency of salt removal capacity when using Hydrilla in the column. Finally, the results were analyzed statistically.

RESULTS AND DISCUSSION

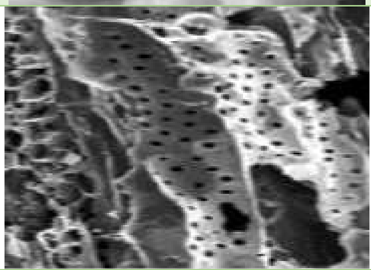
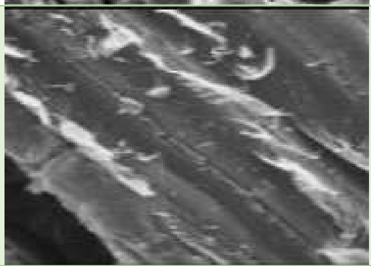
1.1. Characterization of Activated Carbon

Table 3.1: Basic Characteristics of different Activated Carbon

Source of AC	Scientific Name	Moisture (wt. %)	Proximate Analysis (wt. %)			Elemental Analysis (wt. %)					Ash Analysis (wt. % of ash)						
			Ash	Volatiles	Fixed Carbon	C	H	N	S	O	SiO_2	Na_2O	CaO	MgO	Al_2O_3	K_2O	Fe_2O_3
Coconut Shell	*Cocos nucifera*	8	2.05	28.46	69.49	80.13	2.36	1.10	0.06	16.35	37.90	0.90	4.98	1.89	24.12	0.83	15.48
Saw Dust (Jak Tree)	*Artocarpus heterophyllus*	10	0.64	23.66	75.70	83.75	1.23	0.30	0.05	14.67	62.87	0.035	10.35	4.18	9.85	1.71	4.45
Bamboo	*Bambusoideae*	9.54	0.53	75.55	14.38	50.85	5.40	0.38	0.04	42.75	7.64	0.21	6.34	12.70	0.48	30.50	0.39
Water Melon Peel	*Citrullus lanatus*	13	13.36	72.20	14.44	45.41	6.28	0.99	0.21	47.11	69.52	1.20	2.60	1.47	10.78	19.45	0.40

According to the results of the elemental analysis the highest carbon percentage shows efficiency of Activated carbon. Therefore, in proximate analysis highest fixed carbon (75.70%) and elemental analysis highest C (83.75%) was observed in saw dust while lowest percentages are shown in bamboo and watermelon peel. The study further analyzed the least ash oxide percentage in saw dust. Thus, saw dust has the highest adsorption capacity while watermelon peel has the lowest capacity. According to the highest pore spaces available in saw dust it is more relevant to the study area.

Table 3.2: The schematic images of Different Activated Carbon from Scanning Electron Microscope (SEM)

Source of AC	**SEM image (Magnification * 500)**	**Properties**
Coconut Shell		According to the image large pore spaces occurred. Pore volume is large but the surface area is not large
Saw Dust		There are many small pore spaces with a large surface area. Therefore, adsorption capacity is very high
Bamboo		Very limited pour spaces. Thus adsorption is less favourable.
Watermelon peel		Large but very limited pour spaces occurred. Least favourable for sorption.

There for high availability pore spaces in large surface area saw dust has highest adsorption when compared to other three sources of Activated Carbon.

1.2. Iodine Number (IN)

Table 3.3: Calculation of IN

Source of GAC	IN
Coconut Shell	0.48
Saw Dust	1.05
Bamboo	0.45
Watermelon Peel	0.18

According to the data highest IN observed in saw dust. Higher the IN betters the adsorption capacity.

1.3. Experimental Data Analysis to prove Freundlich Isotherm

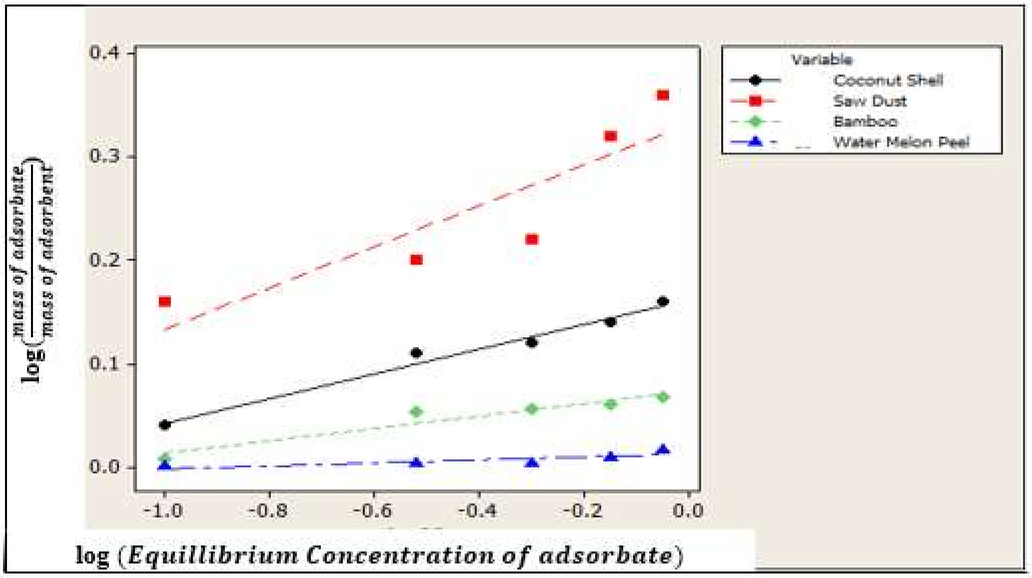


Figure 3.1: Freundlich Isotherm Constant variation of different GAC

According to the Figure 3.1, sorption sites were high in the saw dust and that proves highest sorption capacity occurred in the saw dust. Therefore it has highest correlation and strong linear relationship which proves the freundlich isotherm to sorption sites most favourably. While other sources coconut shell, bamboo and watermelon peel have considerable sorption sites occurred but too lesser decrease compared to saw dust.

1.4. Batch Experiments

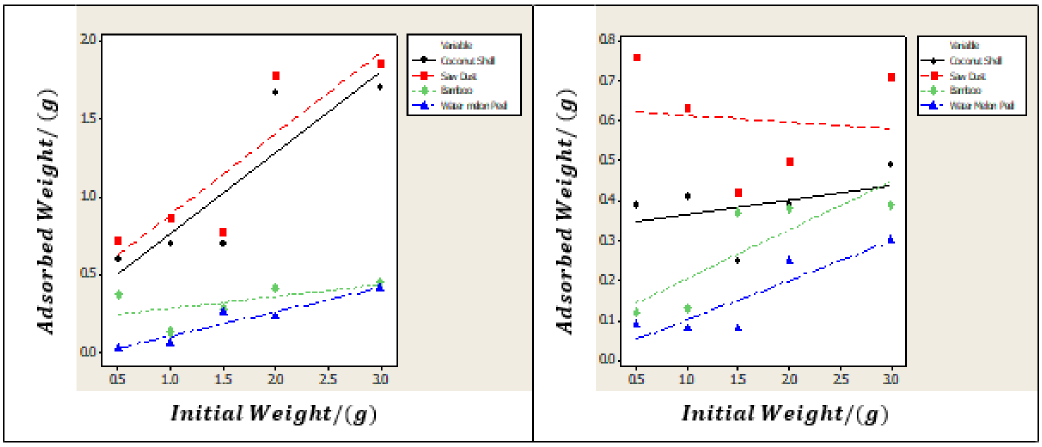


Figure 3.2: SRE when using natural sea water with GAC & PAC of different sources of GAC & PAC

Thus, from all the above statistically analyzed regression graphs proves that GAC was more effective than the PAC when removing the salts of natural sea water. According to the regression analysis GAC and PAC of Saw dust have high Salt Removal Efficiency (SRE) than the other adsorbents in the study. Thus, highest removal capacity occurred in GAC of Saw Dust. Salt removal efficiency of GAC of saw dust was 72.39%

Finally, same batch experiments were done to the synthetically prepared $NaCl_{(aq)}$ solutions and results were almost similar to the natural sea water sample. Furthermore, Batch experiments were done varying the water volume, time and angular velocity to different sources of AC. Results were same as the previous.

1.5. Column Experiments

After statistically analyzed the column results using paired and pooled t – test; results can be summarized

- Salt removal efficiency was relatively high in Saw Dust.
- Salt removal efficiency was relatively high in GAC Salt removal capacity can be increased using *Hydrilla verticillata* as a layer in the filter. (82.98%)

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Desalination process effective with the GAC. When sieve size increased the adsorption efficiency of the GAC increased. Due to the lot of pore spaces availability of Saw dust activated carbon adsorption capacity is vigorously high in saw dust compared to the activated carbon materials. Although low pore spaces in water melon rind eventually have low capacity of adsorption when comparing to the other three it also has a favourable amount of adsorption capacity. When compared to the reverse osmosis technique which was the highest efficiency desalination technique in the world adsorption isotherm technique and membrane filtration process which used in this study has shown a considerable low cost and high efficiency in desalination process. The adsorption data followed the Freundlich Isotherm conforming the consecutive layer model to unlimited sorption sites. This was useful to the physical sorption of the sea water because sea water is a combination of salts. IN is the indication of capacity to adsorb the salts. AC of saw dust had the highest IN. In column studies or membrane filtration process the ratio of amounts (20g) used was; Sand: *Hydrlla verticillata*: GAC of Saw dust: *Hydrlla verticillata*: Sand = 1:1:1:1:1. This ratio has the highest desalination effect. Salt removal efficiency was 83%. The response of *Hydrlla verticillata* depends on the concentration of NaCl. More than two months period the material of the column can use without stagnant and deterioration. Adsorption technique of desalination shows strong positive linear relationship when using GAC of saw dust. The removing capacity of salt was 72%. Water samples were analyzed through Atomic Adsorption Spectroscopy (AAS); after the treatment GAC of saw dust have the significance and considerable decrease in chemical parameters and cation & anion concentrations. Therefore GAC of saw dust have a significance level of salt removing capacity in related to this study. Thus this study show adsorption technique and membrane filtration method using GAC of saw dust was highly effective, environmental feasible way to desalinate the sea water.

Recommendations

Increasing the amount of GAC in the column will increase the efficiency in desalination process. Increase the diameter of the column will increase the rate of desalination.

Thus this water purification or desalination process can be simply identified as the cleaner production technology with the concepts of industrial ecology, industrial symbiosis, greening the supply chain. This can be developed up to a filter using a motor inside the column. Rotating filter will increase the adsorption to the membrane. Therefore it will be low cost, high efficient, environmental friendly method to desalinate sea water.

REFERENCES

Books and eBooks

Abegglen, C, Barry, DA, Chèvre, N, De Alencastro, LF , Kienle, C, Magnet, A , Margot, J, Rossi, L, Schärer, M, Thonney, D & Weil, M 2013, *Treatment of Micro Pollutants in Municipal Wastewater: Ozone or Powdered Activated Carbon, Sci. Total Environ*(2013),pp. 461-462, 480-498

Adham, S, Kumar, M, Liu L & Oppenheimer, J 2007,*Dewatering Reverse Osmosis Concentrate From Water Reuse Applications Using Forward Osmosis, Water Reuse Foundation*, pp. 1-74

Bohn, PW, Elimelech, M, Georgiadis, JG, Marinas, BJ, Mayes, AM & Shannon, MA 2008, *Science and Technology for Water Purification in the Coming Decades*, Nature452, 7185, pp.301-310

Chanan, A, Chekli, L, Kandasamy, J, Phuntsho, S, Shon, HK & Vigneswaran, S 2012, *A Review of Draw Solutes in Forward Osmosis Process and Their Use in Modern Applications, Desalination,* 43(1-3), pp. 167-184

Cornwell, DA & Roth, DK 2011, *Water Quality and Treatment, A Handbook on Drinking Water*, Water Treatment Plant Residuals Management, Chap. 22, J.K. Edzwald 6th eds,

Devasagayam, D 2015, *Solar Energy Based Purification of Sea Water – A Detailed Review*; Volume 02, e – ISSN, 2395 -0056, pp. 7-10

Flemming, HC 1997, Reverse *osmosis membrane biofouling,* Exp. Therm. Fluid Sci. 14, pp.382–391

Hai, FI, Kang, J, Nghiem, LD, Nguyen, LN & Price, WE 2012, *Removal of Trace Organic Contaminants by a Membrane Bioreactor–Granular Activated Carbon (MBR– GAC) System, Bioresource Technology* ,pp. 113, 169-173

Handa, H, Kimura, H, Kondo, M, Matsushita, M, Sugiyama, A & Takahashi, HA 2019, *Filtration and exposure to benzalkonium chloride or sodium chloride to preserve water samples for dissolved inorganic carbon analysis* , Vol 53, pp.305- 318

Lemley AKB & Wagenet, L 1995, *Activated Carbon Treatment of Drinking Water, New York,*pp. 1-5

Liu Y, Guo Y, Gao W, Wang Z, Ma Y & Wang Z 2012, *Simultaneous preparation of silica and activated carbon from rice husk ash,* J Clean Produc. 32, pp.204-209

Maddah, HA 2020, *Adsorption Isotherm of NaCl from Aqueous Solutions onto Activated Carbon Cloth to Enhance Membrane Filtration* , Vol 23, No1, pp.69-78

Van der Bruggen, B, & Vandecasteele, C 2002, *Distillation vs. membrane filtration: overview of process evolutions in seawater desalination, Desalination*, doi: 10.1016/S0011-9164(02)00259-X

Web sources

Patel, CRP, Srivastava, ON, Trpathi, P & Yadav, TP, *Filtration of Sodium Chloride from sea water using Carbon hollow tube composed of Carbon nano tubes*, ISSN:1947 – 5411, Available from, [https://www.tandfoline.com/loi/tsnm20 [25-03-2021]](https://www.tandfoline.com/loi/tsnm20)