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Conversion of putrescible vegetable waste into activated carbon and its utilization for textile waste water treatment

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ABSTRACT

The present study focuses on the conversion of putrescible vegetable waste (PVW) collected from market places to phosphoric acid treated activated carbon (PAC). Physico chemical properties of PAC were studied. SEM EDX, FT IR and XRD revealed that PAC is carbon rich porous activated carbon with various functional groups. BET surface area is about 603.7m^2/g showed that PAC could behave as a good adsorbent material. Batch mode adsorption studies were carried out for the waste water treatment. Textile dye effluents were collected at different periods. Water quality parameters was studied and analyzed before and after adsorption process. It revealed that PAC could be employed as an effective low cost adsorbent for textile waste water treatment.

Keywords: Adsorption, Textile waste water, Putrescible vegetable waste, Batch mode, Activated carbon.

INTRODUCTION

Overall generation rate of solid waste for the entire community needs a proper design of solid waste management system. Throughout the human history, water has been a source of life as well as death. The body is mostly H_2O and a large amount of water is consumed for various industrial purposes. Food and food processing industry generate wastes, effluents, residues, and by-products that can be recovered and can often be upgraded to higher value and useful products. The food industry produces large volumes of wastes, both solids and liquids, resulting from the production, preparation, and consumption of food. These wastes pose increasing disposal and potentially severe pollution problems and represent a loss of valuable biomass and nutrients. In the past they often have been dumped or used without treatment for animal feed or as fertilizers.

Besides their pollution and hazardous aspects, in many cases, food processing wastes might have a potential for recycling raw materials or for conversion into useful products of higher value as a by-product, or even as raw material for other industries, or for the use as food or feed/fodder after biological treatment [1]. Particularly, the bioconversion of food processing residues is receiving increased attention regarding the fact that these residual matters represent a possible and utilizable resource for conversion to useful products like activated carbon or bio-sorbents [2]. Adsorption has been found to be an efficient and economically cheap process for removing dyes [3].

Many research works has been carried out for the proper disposal of vegetable wastes into value added products. Certain processes like vermicomposting AJC [4], incineration [5]and anaerobic digestion [6] were carried out for the conversion of vegetable wastes into useful products. Also conversion of vegetable residues into bio-adsorbents for waste water treatment was also suggested [1].On the other side, efforts were also made to find an alternate and appropriate technology for the removal of textile dyes from the effluent water.

Adsorption onto activated carbon is proven to be very effective in the removal of textile wastes and there is a constant search for highly efficient low cost adsorbent. Such types of adsorbents include groundnut shell [7], peanut hull [8], coconut shell [9], ricinus communis [10], jackfruit peel [11]and citrus reticulata [12].In the present study, a novel attempt has been made to convert putrescible vegetable waste available free of cost into activated carbon. The main objective of this study was to develop a novel low cost adsorbent from putrescible vegetable waste through chemical activation method and also to study its application to treat textile waste water.

MATERIALS AND METHODS

Preparation of Activated Carbon

Activated carbon was prepared using putrescible vegetable waste (PVW) which was collected from market places, kitchens of college hostels and marriage halls in and around Coimbatore city, Tamilnadu, India. All types of vegetable wastes used in the region and their peels were collected in the course of one year.

The dried PVW to be carbonized is impregnated with a boiling solution of 30 % H_3PO_4 for 2 hours and soaked in the same solution for 24 hours. At the end of 24 hours, the excess solution decanted off. The air dried and was carbonized in muffle furnace at 400^0C. The dried material was powdered and activated in a muffle furnace at 800^0C for a period of 10 minutes. Finally the activated carbon (PAC) was washed with plenty of water to remove residual acid and then it was dried and powdered [13].

Textile waste water collection and analysis

Water samples were collected (5 samples) from the Common Effluent Treatment Plant (CETP) at Tiruppur at five different periods. PAC prepared was used for the treatment of various samples collected by batch mode adsorption studies. Effect of adsorbent dosage and effect of time were studied using the best activated carbon.

Batch mode adsorption studies

Batch mode adsorption was employed to conduct the experiment which helps in designing an efficient water treatment plant. Several advantages of conducting experiments in batch mode technique are cheap and less time consuming, easy to interpret the results and do not depend on number of variables. Hence the study of any adsorption system in batch mode carries prime importance.

RESULTS AND DISCUSSION

The physico-chemical characteristic of PAC is given in Table 1. The values show that PAC has got better porosity, good surface area and also higher iodine number[14]. It concludes that PAC could be a better adsorbent.

Table 1. Physico-Chemical characteristics of PAC

Parameters	Values
Moisture content (%)	4.5
Ash content (%)	8.37
Water soluble content (%)	19.26
Acid soluble content (%)	1.63
Volatile matter (%)	20.5
Iodine number (mg/g)	1101.9
Methylene blue number	525
Bulk density (g/ml)	0.388
Specific gravity	0.98
Porosity	60.4
pH	6.65
pH_{ZPC}	6.87
Electrical conductivity	0.151
Yield (%)	76.48
BET Surface area (m^2/g)	603.7
Total pore volume (cm^3/g)	0.7053
Average pore diameter (A^0)	46.74
Langmuir surface area (m^2/g)	2469

It was further supported by SEM image of PAC in Figure 1. To explore the surface characteristics of PAC, a FT-IR (Model: FT-IR-2000, Perkin Elmer) analysis was performed in the range of 400 – 4000cm^{-1}. IR spectrum PAC is shown in Figure 2. The peaks 3444cm^{-1}, 2918cm^{-1}, and 2858 cm^{-1} are ascribed to N-H groups, asymmetric C-H band and symmetric C-H bands of methyl and methylene groups respectively[16]. The peaks at 2357cm^{-1}, 1612 cm^{-1} and 1159 cm^{-1} are assigned to C≡C alkyne functionality, C=C vibrational band and C-O band respectively[17]. All these functional groups are responsible for the enhancement of adsorption properties.

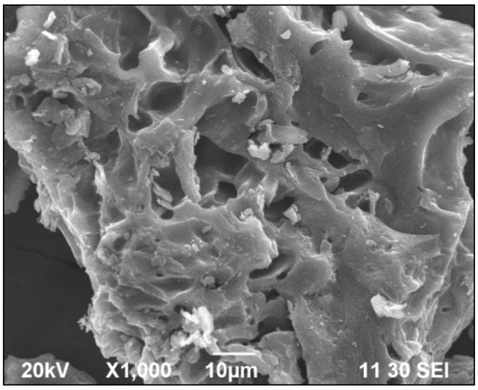

Figure1. SEM image of PAC

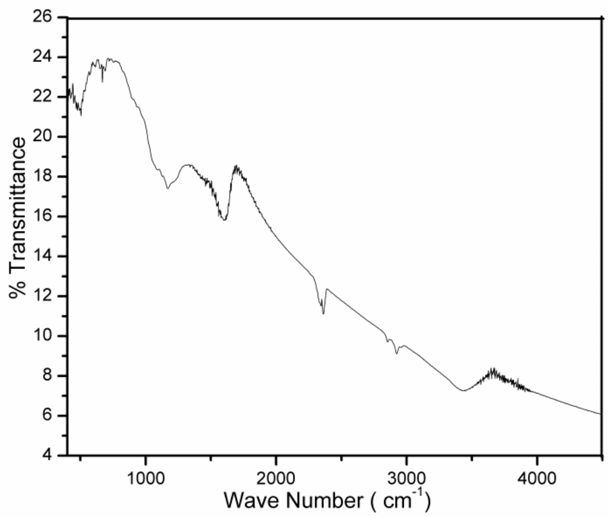

Figure 2: IR spectrum for PAC

X-ray diffraction analysis show broad peaks at 2θ values 23.13, 26.5 and 24.2 which indicate the presence of amorphous form of carbon (Figure 3). It does not give any major peak which could be due to lack of inorganic substances in the activated carbon [18]. SEM EDX analysis was done to find out the elements present and it revealed that PAC has Carbon 48.66, Oxygen 36, Phosphorous 13.09, Hydrogen 2.1 and Sulphur 0.15 by weight percentage.

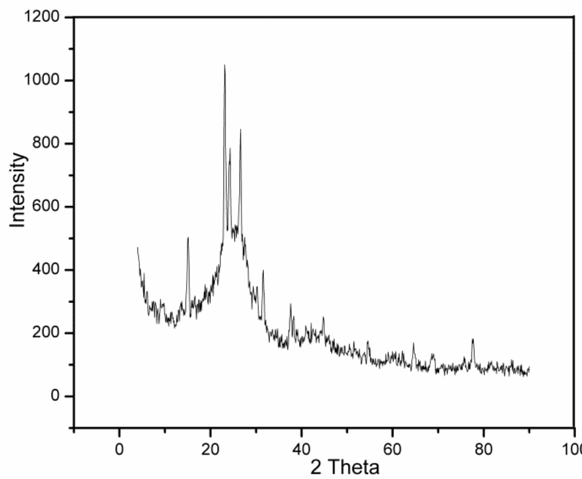

Figure 3: XRD spectra for PAC

Characterization of Effluent Samples Before and After Adsorption

The main purpose of effluent analysis is to evaluate better – performing, advanced treatment methods with the aim of reuse, recovery of valuable products or safe disposal. On the other hand, this helps to evaluate the efficiency of the treatment system by analyzing the pollutant level remaining in the treated effluent. Above all, the quality of water should be known prior to its release into the environment [19].

The effluent parameters before and after treatment are presented in Table 2. From the table it is clearly understood that PAC completely removes the colour from the samples 1, 4 and 5. pH of the samples determine whether the sample is acidic or alkaline in nature. It is clear from the table that before treatment they were highly alkaline in nature. After treatment with PAC it was seen that sample 1and 4 are slightly alkaline, sample 3 and 5 are slightly acidic and sample 2 is acidic in nature. pH values in all the samples except 2 are within permissible limit [20].

Table 2 Characteristics of effluent samples before and after treatment

Parameters	MAL*	Sample 1		Sample 2		Sample 3		Sample 4		Sample 5	
		BT	AT	BT	AT	BT	AT	BT	AT	BT	AT
Colour	Colorless	Blackish green	Clear	Dark blue	Pale grey	Reddish black	Pale red	Black	Clear	Dark green	Clear
pH (at 25^0C)	6.5-8.5	10.3	8.5	9.6	3.94	11.1	6.78	10.8	7.6	11.7	6.62
Turbidity (NTU)	5-10	34	7	45	4	38	4	51	3	28	ND
BOD (20^0)C, 3 days, mg/L)	max 30	28	ND	45	ND	52	12	32	ND	41	5
COD (mg/L)	max 250	860	72	580	55	430	45	400	50	345	42
TDS (mg/L)	500-2000	4110	2466	5274	3567	5040	3356	2727	1024	2012	1267
Total hardness (mg/L)	300-600	1200	156	799	76	656	80	645	42	384	44
Ca^{2+} (mg/L)	75-200	240	44	348	40	251	44	300	30	224	30
Mg^{2+}(mg/L)	30-150	219	36	546	35	325	36	181	10	204	12
Total alkalinity (mg/L)	200-600	950	242	1124	180	786	211	815	174	642	80
Chloride (mg/L)	200-600	622	181	220	60	408	60	392	80	361	60
Sulphate (mg/L)	200-400	1080	534	612	15	400	10	128	5	135	4

**Maximum Acceptable Limit as per BIS standard* *ND – Not detectable*

Turbidity is measured using Nephelometric turbidity meter and in all the samples turbidity is reduced to a greater extent [21]. Biological oxygen demand (BOD) and Chemical oxygen demand (COD) are the indicators of excess organic matter and chemical compounds in water respectively. The maximum permissible limit of BOD is 30 mg/L. After treatment, in the samples 1, 2 and 4 the BOD is not detectable and in samples 3 and 5 minimum BOD is observed [22]. Before treatment, COD is higher in all the samples and after treatment there was a considerable decrease in COD.

An appreciable decrease in the total dissolved solids in all the samples was not observed. Total hardness in any water sample reflects the nature of all geological formations with which it has been in contact. The limit of hardness should not exceed 600 mg/L for any water sample [23]. In all the samples initially the total hardness level was higher and after treatment with PAC it decreased to a greater extent.

The presence of calcium in water sample is due to over deposits of limestone, dolomite and gypsum, which contributes to the total hardness. The calcium level should be within 75 – 200 mg/L. In all the effluent samples, the calcium level was well below the lower acceptable limit. Similar analysis of calcium was done by [24] and was reported to have higher levels of calcium.

Magnesium is a common constituent of natural water and an important contributor to the hardness of water. It forms scales in boiler when water containing magnesium is heated. It should be within the limit of 30 – 150 mg/L. It was observed that all the samples exhibit lower magnesium level nearing the acceptable limit as per BIS (1991) [25].

Alkalinity of all the samples was found to be within the limits after treating them with the activated carbon. Chloride content is lower even before the treatment and it became much lower after treatment with PAC [26]. Sulphate content considerably decreased after treatment except sample 1 [27].

From all the above analysis, the effluent quality was found to satisfy the water quality parameters as per the BIS (1991) standard. Hence it could be proved that phosphoric acid activated carbon (PAC) prepared from putrescible vegetable waste (PVW) is an effective adsorbent which removes pollutants like dye content from dyeing industry effluents. Further some secondary treatment methods could be adopted to improve the quality of the effluent.

CONCLUSION

Various conclusions can be drawn from the present study. Peels from various vegetable matters were collected from the kitchens of hostels, hotels and marriage halls and also from market places. Putrescible vegetable waste, a municipal solid waste generated is utilized for the preparation of activated carbon does not involve any raw material cost. SEM analysis of all the activated carbons revealed that they are highly porous in nature. The SEM EDX analysis found that carbon is present in a higher percentage.

FT-IR studies predicted surface functional groups like –OH and some groups like C-H, C=C and C=O. The XRD pattern of the carbons reveals that they are amorphous in nature with few crystallite formations. BET surface area analysis revealed that the surface for PAC 603.7m^2/g proved it to be a best adsorbent.

Five different real effluent samples are collected from common effluent treatment plant and PAC is used for its treatment. It is found that the effluent samples before treatment showed higher values for all the water quality parameters. After treatment with PAC, the effluent quality is at par with the water quality parameters as guided by BIS 1991 standards. Thus the study clearly suggests a solution for solid waste management as well as dye effluent treatment.

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