https://doi.org/10.36375/prepare_u.iiche.a410

Characterization and Adsorption Performance Evaluation of Waste Char

Arka Sanyal[a], Manoj Kumar Sonthalia[b], Abhijit Kundu[c], Aparna Ray Sarkar*[d]

[a,b,c]*Undergraduate student, Department of Chemical Engineering, Heritage Institute of Technology, Chowbaga Road, Anandapur, East Kolkata Township, Kolkata, 700107, India*

[*d]*Assistant professor, Department of Chemical Engineering, Heritage Institute of Technology, Chowbaga Road, Anandapur, East Kolkata Township, Kolkata, 700107, India*

Abstract

Environmental threats such as global warming, soil contamination, ground water pollution and air pollutions are the penalties of the huge generation of wastes from industries and urban areas. Therefore, waste management has become an important issue. An effective waste management includes prevention, reuse, recycling, recovery and disposal of waste. Several technological approaches have been explored to attain any one of the processes. Waste to energy (WTE) conversion is well accepted. Pyrolysis is one such promising technology which can produce three different types of fuel such as, pyro-oil, char and gases from solid or liquid wastes. This pyro char can be used as a good adsorbent. On the other hand industrial effluent contain heavy metals like Lead (Pb), Arsenic (As), and Cadmium (Cd), as well as harmful anions like fluorides, nitrates, and sulphates, which cause extensive damage to our environment. Hence, treatment of industrial effluents is utmost important. In this present study, char material will be prepared from pyrolysis of waste materials and will be used for the liquid phase adsorption of Eosin y. Adsorption isotherm will be evaluated. Characterization of adsorbent will be done. The removal of pollutants from waste water solution using this adsorbent will be presented.

Keywords: Pyro char; adsorption isotherm; solid waste; wastewater treatment; industrial effluent treatment

1. Introduction

Electrical and Electronic Equipment (EEE) such as monitors, screens, lamps, temperature exchange equipments, telecommunication and information technology equipments, mobile parts etc. has been defined as E-wastes when extended to annihilation. The E-waste generation increases gradually due to the rapid technological change and growth which forces people, companies and institutes to replace the EEE very frequently. According to a recent survey only 17.4% of 53.6 X 10^6 metric tons of e-waste was recycled in 2019[1]. E-waste

https://doi.org/10.36375/prepare_u.iiche.a410

contains heavy metals, chloroflurocarbons and brominated flame retardants (BFR) which leads to drastic risk to the environment and human health[2]. However, there is a still dearth of effective technologies and infrastructure to recycle or treat or manage these E-wastes. Therefore, environmentally sound treatment methodologies are required in E-waste management sector.

Pyrolysis is a thermochemical process that involves the decomposition of organic materials, such as biomass, plastics, and rubber at a temperature of 300 to 1000ºC in the absence of oxygen. Under pyrolysis condition, these materials are decomposed into volatile gasses, liquids, and solid char. This method not only converts the waste materials in to high density fuels, it also recovers value added materials. on industrial waste water to remove impurities and an indirect path of E-waste minimization. The char which is obtained from pyrolysis of E-wastes has been used in this present study as an adsorbent. This way the E-waste can be reused in waste water treatment sector.

In this respect, this paper aims to present a treatment methodology which can be applied

Several studies, have been reported on the adsorption characteristics of the char obtained from pyrolysis of corn cobs [3]. But studies on adsorption characteristics using eosin y, have not been reported. In this present study the determination of adsorption isotherm of E-waste generated pyro-char material using eosin y dye Eosin y dye has been. The impurities removal efficiency of has been calculated. Waste water characterizations have been done. Pyro char is an inexpensive adsorbent that can remove heavier impurities and metals to a certain degree. This will certainly reduce the cost of treating effluents and make it economical for the interested parties.

2. Materials and methods

2.1 Chemicals

Analytical grade chemicals (Eosin y dye, NaOH) were acquired from Sigma Aldrich. Deionized waters were obtained from laboratory. Industrial wastewater sample was procured from the Sulphuric Acid Plant (SAP) of a fertilizer industry.

2.2 Synthesis of adsorbent from pyrolysis of char

E-waste specially Printed Circuit Boards (PCB) (computer motherboard, mini circuit of remote controls, smartphones, calculators, etc.) were collected from local shop near Ruby market. Collected e-wastes were shredded. Pyrolysis experiments were conducted of shredded PCB at around 550°C for 1 hour. The pyro-char obtained was set to cool down at room temperature. Pyro char was washed with conc. NaOH solution to wash away heavy metals remaining in the char.

2.3 Dye adsorption experiments

Batch adsorption tests were carried out in 100 mL Erlenmeyer flasks at room temperature (27◦C) containing Eosin y dye within 40 – 5 mg/L with a varying adsorbent dose of 7gm to 0.5 gm. The pH was set between 5 and 6. For pH adjustment, dropwise addition of NaOH or HCl solutions (1 or 0.1 M) was carried out. The PCB char adsorption isotherms were obtained after adsorbent–dye solution contact for 3 to 1 h, keeping constant the adsorbent dose. The same procedure was replicated for NaOH treated pyro char. Aqueous samples were filtered with Nylon Filters (0.90 μm), and the concentration of Eosin y in water was obtained by colorimeter (Chemiline CL610) at a wavelength of 570nm [4]. Adsorption experiments were carried out in triplicate, and the average value was represented. The relative standard deviation was lower than 5%.

Adsorption isotherms are carried out to evaluate the maximum adsorption capacity. Three isotherm models of linear isotherm (eqn. (1)), Langmuir isotherm (eqn. (2)), and Freundlich isotherm (eqn. (3)) are adopted for the non-linear fitting [5].

$$q = KC_e \tag{1}$$

$$q = \frac{q_0 C_e}{K_L + C_e} \tag{2}$$

$$q = K_f C_e^n \tag{3}$$

Where, C_e (mg/L) is the equilibrium concentration of dye, K is a constant, q is the concentration in the solid phase, q_0 is the maximum monolayer adsorption capacity, k_L is the Langmuir constant, k_f and n are constants.

2.4 Char characterizations

https://doi.org/10.36375/prepare_u.iiche.a410

XRD analysis of this pyro char was performed considering the range of 2θ values from 10 to 90. Surface charge analysis of the char was also done using Zetasizer 2000.

2.5 Adsorption studies of industrial effluent

Batch adsorption studies were carried out in 100 mL Erlenmeyer flasks at room temperature (27 °C) containing industrial effluent within 40 – 5 mg/L with an adsorbent dose of 0.5gm. The pH was set between 5 and 6. The PCB char adsorption experiment had adsorbent–waste water solution contact for 3hrs, keeping constant the adsorbent dose. The treated sample was measured for their TSS using a Systronics Digital Nephelo/Turbidity meter calibrated to zero using laboratory grade de-ionised water. Since the wastewater we obtained was mostly neutral with baseline level TDS, only the TSS change was observed and recorded for this specific experiment.

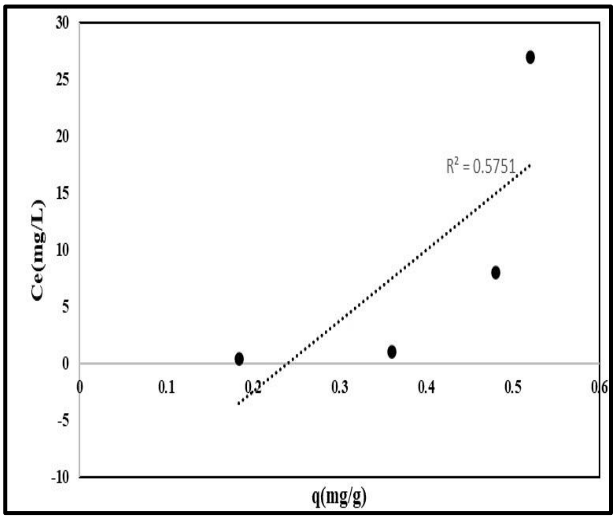

Figure 1(a): Linear Isotherm

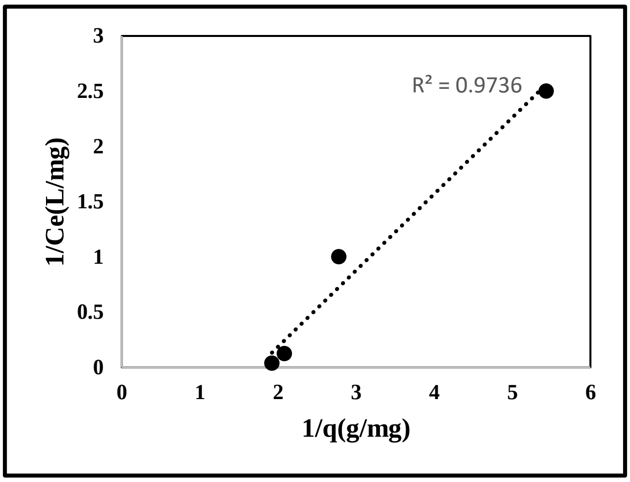

Figure 1(b): Langmuir Isotherm

3.Results and discussions

3.1 Adsorption isotherm

https://doi.org/10.36375/prepare_u.iiche.a410

Experimental data for the dye adsorption isotherms in the PCB char are modeled using three models. Using these experimental data three different plots were constructed namely, Figure 1(a) (Linear model), Figure 1(b) (Langmuir isotherm) and Figure 1(c) (Freundlich isotherm). By tracking Ce vs q for Linear isotherm, 1/Ce vs 1/q for Langmuir isotherm, and log Ce vs log q for Freundlich isotherm are checked, if a straight line is obtained. According to these results, the correlation coefficient of the Linear isotherms is equal to 0.575, Langmuir model is equal to 0.973, and the Freundlich correlation coefficient of 0.575.

This means that the process of Eosin y adsorption by PCB char is perfectly described by Langmuir model. Table 1 represents the values of the adsorption equilibrium parameters according to the Langmuir model.

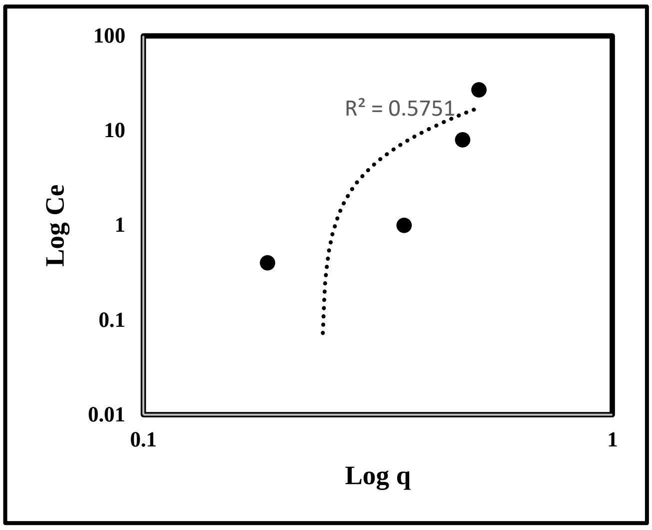

Figure1(c): Freundlich Isotherm

https://doi.org/10.36375/prepare_u.iiche.a410

Table 1: The values of the adsorption equilibrium parameters of Langmuir isotherm model

Sl. No.	Equilibrium parameters	Values
1.	Intercept	1.731
2.	q_o	0.577mg/g
3.	K_L	1.259
4.	R^2	0.973

Here, q_0 is the maximum dye adsorption capacity per gram of char, and K_L is the Langmuir constant. Both of these data are found out from the intercept and slope of the graph.

3.2 Adsorption kinetics

3.2.1 Effect of adsorbent load on dye removal:

Adsorption load has a major role in adsorption studies because it determines the adsorption capacity for a given initial concentration of dye. Experiments were conducted to understand the effect of PCB char on Eosin y taking initial dye concentration 40 mg/L. The adsorbent loads are varied from 0.5 to 7gm. Figure 2 shows the effect of adsorption load on percentage of dye removal.

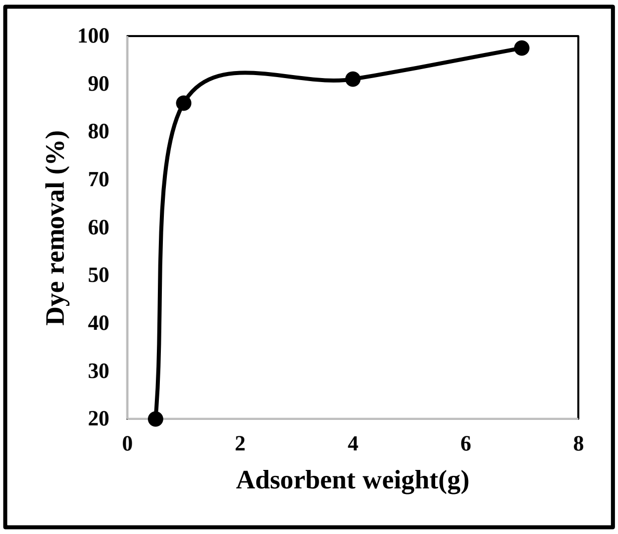

Figure 2: Dye removal vs Adsorbent

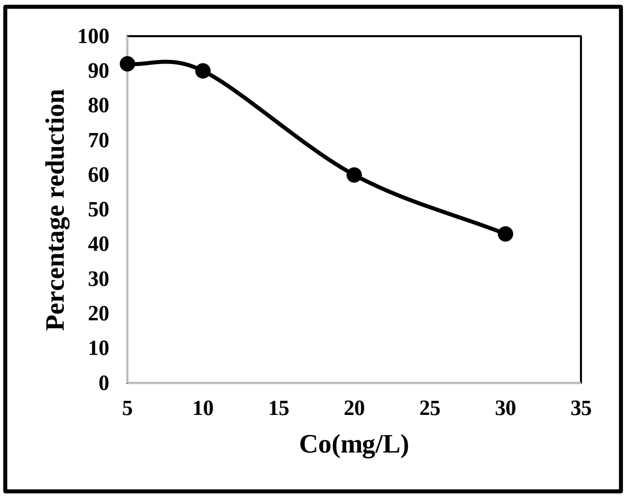

Figure 3: Percentage removal of dye vs initial concentration

It is clear from the figure that the removal rate of dye solution increased sharply as the adsorbent loads were increased. The maximum dye removal efficiency was 97.5% at a dosage of 7gm. The increased adsorbent load shares

https://doi.org/10.36375/prepare_u.iiche.a410

large surface area as well as exchangeable active sites.

3.2.2 Effect of initial dye concentration:

The dye concentration also plays a vital role in adsorption studies to evaluate the adsorbent capacity. In this study four different dye concentrations, 5, 10, 20 and 30 mg/l were selected to study the effect of the initial dye concentration on the adsorption of dye on PCB char. The other process parameters such as adsorbent load, temperature and pH were kept constant. The dye removal percentage is inversely related with the initial dye decreased as the initial dye concentrations were increased. The percentages of dye removal decreased from 92 to 43% as the initial dye

concentration. Figure 3 shows the effect of initial dye concentration on adsorption capacity. The percentage of dye removal

On the contrary, the surface charge of PCB char was found to be highly negative. The value of zeta potential is -9.494 mV. Since the Eosin y dye ions are positively charge, they gets attracted towards negative surface of the char. Additionally, increase in dye concentration, blocked the char pores and hindered effective adsorption. Therefore, dye removal decreased with increase in dye concentration.

3.2.3 Effect of contact time:

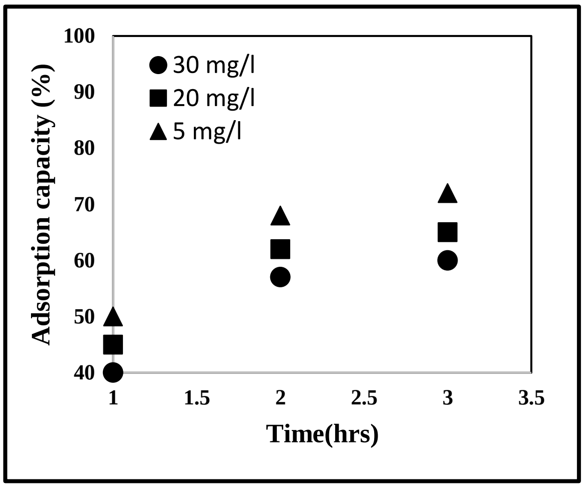

Figure 4: Adsorption capacity vs Time

Figure 4 illustrates the effect of contact time on adsorption capacity of PCB char. Three different experiments were conducted, 1, 2 and 3 hr and the effects were observed at different concentrations, 5, 20, 30 mg/l to investigate the adsorption capacity. The adsorbent load was kept constant. The result shows that the equilibrium time is independent on initial concentration of dye. Initially the adsorption capacity increased rapidly as all the vacant active sites are available. But after certain prolonged contact time equilibrium were reached due to the lack of free active sites availability.

3.3. XRD analysis of PCB char:

XRD analysis of the PCB pyro char sheds light on the overall crystallinity of the material and which compounds contribute towards its crystallinity. Figure 5 shows the shows the XRD spectrum for the char.

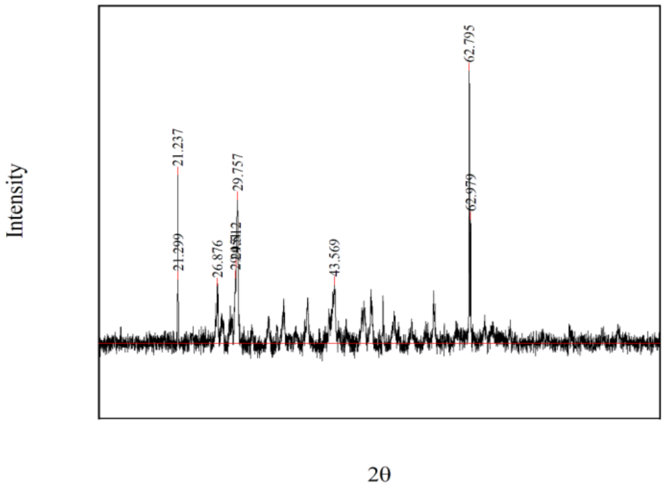

Figure 5: XRD data graph

From the figure peaks are evident at 2θ = 21^0, 29^0 and 62^0. The sharp peaks indicate crystallinity. The material is mostly amorphous. At 2θ= 63° and 21° the peaks resemble the presence of Silica. At 2θ= 43° contributes to the presence of Copper, and an unknown compound with empirical formula $Al_3Ca_{0.5}Si_3O_{11}$ presents itself at 2θ=29° [6][7][8][9]. Crystallinity index of the compound was found out to be 10.13%. This data reveals low crystallinity of pyro char.

3.4 Adsorption of Industry effluent:

A big part of cleaning up industrial effluent is removal of suspended solids. TSS(Total Suspended Solids) gives us an idea of turbidity of a solution. Table 2 shows that the turbidity decreases significantly after adsorption treatment. To put that into perspective, raw effluent passed through two filter papers has a turbidity value higher than that of treated effluent.

https://doi.org/10.36375/prepare_u.iiche.a410

Table 2: TSS values before and after adsorption

Samples	Turbidity (NTU)
Raw effluent	2.2
Treated effluent	1.2
Double filter paper	1.9

4. Conclusions:

From our study, the following conclusions can be drawn:

Pyro char obtained from pyrolyzing PCB, is an amorphous material with a surface charge of -9.494. All of which are great indicators for a good adsorbent. The negative surface charge explains the affinity towards eosin y dye, which is positively charged, and indicates a possibility for heavy metal ion removal.

The Pyro char follows Langmuir model isotherm for the adsorption of eosin y dye. This means that the adsorbate particles (here, eosin y molecules) form a monolayer over the exposed adsorbent surface, after which the adsorbent is saturated. As a result in this study; the percentage removal of dye decreases with increase in concentration of dye solution, the adsorbent becomes saturated. This also means, percentage removal of dye increases with increase is surface area of the adsorbent or in the case of our study, increase in the amount of adsorbent will result in an increased removal of dye molecules from the solution.

The Pyro char can effectively clear up turbidity from industrial effluent. In this study, effluent of Sulphuric Acid Plant was used with 2.2NTU TSS. After treating it with pyro char, TSS became 1.2NTU. At the same time, a comparative test by passing the raw effluent through two laboratory grade filter papers were done, the resulting TSS was 1.9NTU. Comparatively, pyro char provides an effective cleaning of industrial effluent.

Pyro char washed with conc. NaOH is unfit as an adsorbent. It gave us inconclusive results for the dye adsorption experiment.

These conclusions are quite valuable and thus prove that PCB pyro char can be used as a cheap and effective adsorbent for industrial effluent treatment.

Conflict of interests: The authors declare that they have no conflict of interest.

Appendix:

Ce	equilibrium concentration
K	a constant
q	concentration in the solid phase
q_0	maximum monolayer adsorption capacity
K_L	Langmuir constant
K_f	Freundlich constant
N	a constant
Co	Initial concentration
PCB	Printed Circuit Board
SAP	Sulphuric Acid Plant

References:

1. Forti, V., Bald´e, C.P., Kuehr, R., Bel, G., (2020). The global E-waste monitor (2020): quantities, flows, and the circular economy potential. United nations university (UNU)/United nations institute for training and research (UNITAR) – co-hosted J. Joo et al. 11 SCYCLE programme. In: International Telecommunication Union (ITU) & International Solid Waste Association (ISWA) (Bonn/Geneva/Rotterdam)
2. Yl¨ a-Mella, J., Poikela, K., Lehtinen, U., Tanskanen, P., Roman, ´ E., Keiski, R.L., Pongracz, ´ E., (2014). Overview of the WEEE Directive and its implementation in the Nordic Countries: national realisations and best practices. *J. Waste Manage. 2014, 457372.* https://doi.org/10.1155/2014/457372
3. El-Hendawy AN, Samra SE, Girgis BS. (2001). Adsorption characteristics of activated carbons obtained from corncobs. *Colloids and Surfaces A: Physicochemical and Engineering Aspects, 180, 3,* 209–221. https://doi.org/10.1016/S0927-7757(00)00682-8
4. Koegl M, Weiß C, Zigan L. (2020). Fluorescence Spectroscopy for Studying Evaporating Droplets Using

the Dye Eosin-Y. *Sensors*. *20 (21)*, 5985. https://doi.org/10.3390/s20215985

5. Salman MS. (2009). Removal of sulfate from waste water by activated carbon. *Al-Khwarizmi Engineering Journal*, *5*, *3*, 72-76. https://doi.org/10.1016/j.jenvman.2018.02.096
6. ONO H, DODBIBA G, FUJITA T. 2010. Copper Recovery from Printed Circuit Board by Carbonization. *International Journal of the Society of Materials Engineering for Resources*, *17 (1)*, 53-57. https://doi.org/10.5188/ijsmer.17.53
7. Shen Y, Chen X, Ge X, Chen M. (2018). Chemical pyrolysis of E-waste plastics: Char characterization. *Journal of environmental management*, *214*, 94-103. https://doi.org/10.1016/j.jenvman.2018.02.096
8. Khayyam Nekouei R, Pahlevani F, Golmohammadzadeh R, Assefi M, Rajarao R, Chen YH, Sahajwalla V. (2019). Recovery of heavy metals from waste printed circuit boards: statistical optimization of leaching and residue characterization. *Environmental Science and Pollution Research*, *26*, 24417-24429. https://doi.org/10.1007/s11356-019-05596-y
9. Khayyam Nekouei R, Maroufi S, Assefi M, Pahlevani F, Sahajwalla V. (2020). Thermal isolation of a clean alloy from waste slag and polymeric residue of electronic waste. *Processes*, *8(1)*, 53. https://doi.org/10.3390/pr8010053