Removal of Phenol from Waste Water by using Saw Dust

Bhausaheb Karbhari Sonawane[1] Mithun Motiram Gangadware[2]
[1,2]Sanjivani K. B. P. Polytechnic Kopargaon, India

Abstract— Phenol is a major pollutant in the wastewater because of its presence in the effluent of more processing and refining plants. Suitable method for phenol removal can be selected based on availability of the material, extent of separation required and properties of phenolic effluent. Locally available sawdust, a very low cost and promising material was tested experimentally as an adsorbent, after carbonization, for the removal of phenol from industrial waste waters for a safe disposal. The experiments were performed in batch wise to remove phenol from synthesized aqueous solutions. The equilibrium of adsorption was determined as a function of the solution, contact time, adsorbent dose. Adsorption isotherms of phenol for adsorbents were determined and correlated with the usual isotherm equations such as Langmuir and Freundlich. Equilibrium model analysis indicates the fitness of Langmuir Isotherm model (R2=0.9943) to Phenol-Sawdust adsorption system.

Key words: Phenol, Sawdust, Langmuir and Freundlich, Adsorption

I. Introduction

Fast population growth, industrial expansion, rapid urbanization, use of energy and generation of wastes from domestic and industrial sources have rendered many water sources unwholesome and hazardous to man and the environment in most countries including India. Wastewater is characterized in terms of its chemical, physical and biological composition. In South Africa, typical industries which produce significant volumes of wastewater include textile, steel mills, mineral processing, paper and fiber plants, chemical and fertilizer plants, breweries, refining and petrochemical operations, poultry processors and meat packers, fruit and vegetable packing operations and many more. Wastewater treatment can be done using three methods: primary, secondary and tertiary/advanced processes. Primary treatment separates suspended solids and greases from water and a secondary treatment such as biodegradation process is used in the removal of biodegradable compounds whilst tertiary/advanced treatment methods are largely used to remove non-biodegradable wastes.

Phenol is the priority pollutant since it is toxic and harmful to organisms even at low concentrations. Beside the toxic effects, phenolic compounds create an oxygen demand in receiving waters, and impart taste and odor to water with minute concentrations of their chlorinated compounds. Surface and ground waters are contaminated by phenolic as a result of the continuous release of these compounds from petrochemical, coal conversion and phenol producing industries. Therefore, the waste waters containing phenolic compounds must be treated before their discharging into the water streams. Conventional methods for the removal of phenolic pollutants in aqueous solutions can be divided into three main categories: physical, chemical and biological treatment. Among them, physical adsorption method is generally considered to be the best, effective, low-cost and most frequently used method for the removal of phenolic pollutions. Therefore, the search for low cost and easily available adsorbents has led many researchers to search more economic and efficient techniques of using the natural and synthetic materials as adsorbents. Recently, using the inorganic materials as adsorbents has become one hot research field. Adsorption, as a simple and relatively economical method, is a widely used technique in the removal of pollutants. Although the adsorbents used may vary due to the change in adsorption conditions depending on the type of pollutants, the properties affecting the efficiency of an adsorbent are; a large surface area, the homogeneous pore size, well defined structural properties, selective adsorption ability, easy regeneration, and multiple use. Since the synthetic adsorbents satisfying most of these conditions are relatively expensive, use of natural adsorbents is an active area of research. The aim of the present work is to investigate the capability of industrial sawdust used as an adsorbent for removal of phenol from wastewater and to study the effects of initial phenol concentration, adsorbent dosage, pH value and contact time on the adsorption process, then, find then optimum conditions. In addition, the equilibrium isotherms Langmuir and Freundlich models were determined using the optimum conditions selected from the statistical design of experiments.

Non-biodegradable contaminants pose a serious health and environmental hazard and removal of these wastes cannot be achieved using secondary methods. Hence, tertiary/advanced wastewater treatment methods such as ion exchange, precipitation, membrane separation, electrolysis and adsorption can be used to remove these recalcitrant wastes. However, most of these methods are costly and require high level of expertise; hence they are not applied by many end-users. For these reasons, adsorption technology has gained a wider application due to its inherent low cost, simplicity, versatility and robustness. The success of an adsorption process starts with the choice of an adsorbent. Several adsorbents can be used to treat industrial wastewater. A few of such adsorbent materials are commercial activated carbon, zeolites, silica gel and activated alumina. Unfortunately, most of these adsorption media are very costly. Thus, the use of low cost adsorbents derived from agricultural and industrial solid wastes for wastewater treatment has attracted a vast amount of attention in recent years. These waste materials are underutilized and hence they are readily available. Consequently, the use of these low cost adsorbents forms the main focus of this study. Formerly looking in to allowable levels of phenol below is the concentration of phenol which is reported in numerous industrial wastewaters is given in table 1.1 below.

Name of Industry	Concentration of Phenol
Refineries Industry	06-500PPM
Coal processing Industry	09-6800PPM
Coking Industry	28-3900PPM

Petrochemicals manufacturing Industry	02.8-1220PPM

Table 1.1: Amount of Phenol present in various Industrial Effluents.

As phenol is toxic in nature so some controlling bodies all over the globe like the MoEF, Government of India and EPA, USEPA have presented maximum allowable limits of phenol in different classes of water. Originally Phenol is highly toxic in nature and very difficult to lower the concentration by any process, should be minimized at the acceptable limit.

Name of Agency	Class of water	Allowable Permissible limit
USEPA	Wastewater	0.1 PPM
BIS	Drinking	01.0 PPM
WHO	Drinking	01.0 PPB
MoEF	Industrial wastewater	01.0 PPM

Table 1.2: Allowable limits of Phenol in Water

II. Necessity of the Study

1) Phenol is most dangerous to human body even at minimum level should be removed from water and waste water.
2) The highest toxicity level of phenol is an indicating reason to minimize the level and recycle phenolic wastewater to reduce the concentration of Phenol from contaminated waste water.
3) To remove the color from the water.

III. AIM

1) Preparation of low cost adsorbent from saw dust.
2) Classification of adsorbable properties such as Carbon, Hydrogen, Particle Size, Ash Content, Moisture Content etc.
3) Determine the effects of operating conditions such as solution pH, adsorbent dose and initial adsorbate concentration on the adsorption capacities in batch adsorption.
4) Comparison of adsorption capacity of phenol removal of Sawdust.

IV. Health effects of phenol

Phenol has acute and chronic effects on human health. Inhalation and dermal exposure to phenol is highly irritating to skin, eyes, and mucous. These invers affect also known as acute (less than 14 days-exposure) effects of phenol, as shown in table 1.3 below.

Exposure mode	Effects due to exposure
Inhalation	1. Can irritate the nose, throat, and lungs. 2. Higher exposures may cause a build-up of fluid in the lungs.
Oral	1. Ingestion of as little as 1 gram can be fatal to humans.
Eyes	1. Can also cause severe eye damage, including blindness.
Skin	1. Irritating and corrosive to the skin. 2. Little or no pain may be felt on initial contact due to its local anesthetic effect. 3. Skin contact will cause the skin to turn white; later severe burns may develop. 4. Rapidly absorbed through the skin; toxic or fatal amounts can be absorbed through relatively small areas.
Chronic Exposure	1. Repeated or prolonged exposure to phenol or its vapours may cause headache, nausea, dizziness, difficulty swallowing, diarrhea or vomiting. 2. Can affect the central nervous system, liver and kidneys.

Table 1.3 Health Effects Caused by Phenol.

V. Physical properties of phenol

Following table 1.4 shows the physical properties of phenol.

Properties	Values
Molecular weight (g/mol)	94.144
Molar volume (cm^3/mol)	90
Boiling point (^{0}C)	182
Melting point (^{0}C)	43
Auto ignition temperature (^{0}C)	715
Solubility in water (mg/L)	50-100 @ 19
Liquid density (g/cm^3)	1.06
pH of aqueous solution	6
Molecular diffusivity in water (cm/sec)	6.0 x 10^{-4}
Vapour pressure (mm Hg)	0.41 @ 25 ^{0}C
Relative Vapour density	3.24 (air=1)
Air-water partition coefficient, Kaw(25	2.5 x 10^{-5}
Dipole moment	1.450007
Polarizability, Pi	0.89
Liquid surface tension (dynes/cm)	36.5 @ 55 ^{0}C
Acidity constant, pKa(25 ^{0}C)	9.90
Fraction in neutral form at	pH 7 0.998

Table 1.4: Physical Properties of Phenol

VI. Adsorption

Adsorption is the phenomenon of accumulation of large number of molecular species at the surface of liquid or solid phase in comparison to the bulk. The phenomenon of attracting and retaining the molecules of a substance on the surface of a liquid or a solid resulting into a higher concentration of the molecules on the surfaces called adsorption. The substance thus adsorbed on the surface is called the adsorbate and the substance on which it is absorbed is known as adsorbent. The reverse process i.e. removal of the adsorbed substance from the surface is called desorption. The adsorption of gases on the surface of metals is called occlusion.

However adsorption acts as the basic mechanism in various fields such as,

1) Activated charcoal is used in gas masks adsorbs poisonous gases.
2) Adsorption is also used for humidity control and moisture removal.

3) Modern water purifiers employ adsorption technique to remove organic matters from water by using activated carbon.
4) Arsenic poisoning can be treated by adsorption technique using colloidal ferric hydroxide.
5) Oil refining employs adsorption technique.

VII. FACTORS AFFECTING ADSORPTION

Following are the factors that affect the adsorption process.

1) Effect of pH
2) Contact time
3) Temperature and Pressure
4) Concentration
5) Surface Area
6) Types of Adsorbents

VIII. COMPARISONS BETWEEN ADSORPTION AND ABSORPTION

Below table 1.5 shows the difference between Adsorption and Absorption. They are distinguishing from the following properties.

Sr.No.	Adsorption	Absorption
01	It is a surface phenomenon.	It is a bulk phenomenon.
02	The adsorbed substance gets collected only on the surface of adsorbent.	The absorbed substance gets uniformly distributed throughout the body of adsorbate
03	It is accompanied by evolution of heat.	It is not accompanied by evolution of heat.
04	It depends on temperature and pressure.	It is independent of temperature and pressure.
05	It takes place due to unbalanced forces.	It takes places due to porous nature of Substance.

IX. PREPARATION OF ADSORBENT

Sawdust obtained from wooden sawmill and locally used is washed with hot distilled water to remove the water-soluble impurities and surface adhered particles and then dried at 80°C until a constant weight. The sorbent was treated with 1N H_2SO_4 used in the ratio 1/10(sawdust: H_2SO_4, w/w) at 150 ^{0}C for 24 h, then soaked in 1% sodium bicarbonate solution overnight to remove residual acid. Then the treated material was dried in an oven at 105 ^{0}C for 24h. The dry sorbent was crushed into granules, sieved to different particle sizes, and then preserved in desiccators for use.

X. PHYSICOCHEMICAL PROPERTIES OF SAWDUST.

Following are the some Physicochemical Properties of Sawdust and Sawdust Carbon which are used as Adsorbents in the project shown in table 1.6.

Property	Sawdust
Carbon	48.10
Hydrogen	05.80
Nitrogen	15.70
BET Surface Area (m^2/g)	03.00
Apparent Density (g/mL)	0.32
Particle Size (µm)	227.00
Ash Content (%)	07.40
Moisture Content (%)	08.20

Table 1.6: Physicochemical Properties of Sawdust

XI. PREPARATION OF REFERENCE SOLUTION

Solution of 100 mg/l of initial concentration of Phenol was prepared by adding of 0.5 gm AR grade Phenol in 200 ml distilled water. After dissolution both the solutions diluted to the 500 ml with distilled water into 500 ml volumetric flask. Solution is kept for further bath adsorption procedure.

XII. IR SPECTRA STUDY

The IR spectral analysis is important to identify the characteristic functional groups on the surface of the adsorbent, which are responsible for adsorption of phenol ions. It is a graph plotted between % transmission and wave number. These particular graphs used to identify adsorption friendly functional groups that are responsible for adsorption property.

IR Spectra of Sawdust, the graphs taken between the wave numbers 4500 cm^{-1} and 500 cm^{-1} of sawdust. The peaks appearing in the FTIR spectrum were assigned to various functional groups according to their respective wave numbers. Group responsible for adsorption property at 3400-2400 cm^{-1} wave length shows very strong O-H bond. Again 1730-1700 cm^{-1} wave length shows C=O bond. Conjugation moves adsorption to a lower frequency. Again 1320-1210 cm^{-1} wave number shows C-O bond of medium intensity.

XIII. THE CALIBRATION

The calibration curve is plotted for various concentration of phenol. For the calibration of phenol the concentration of 10 mg/L,20 mg/L,30 mg/L,50mg/L,70 mg/L and 100 mg/L solution were prepared from the dilution of the stock solution. Next, maximum wavelength of Phenol and the absorbance value for each sample were taken using UV-Visible Spectrophotometer and the calibration curve was constructed. For future reference, the concentration of a sample can be found directly from the calibration curve using its absorbance value λ max = 270 nm. As shown in fig.01

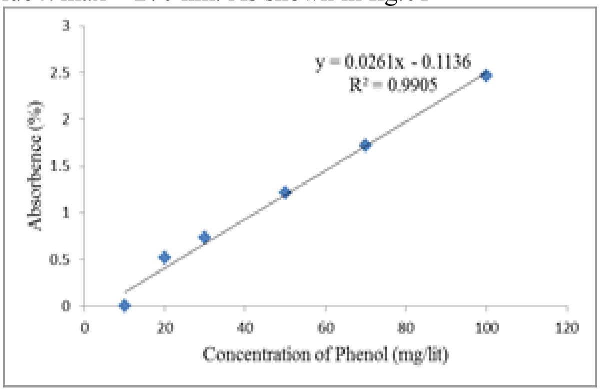

Fig. 01: Calibration graph for Phenol Concentration with % Absorbance

XIV. RESULT & DISCUSSION

A. Effect of Saw Dust (Dose) on Adsorption of Phenol

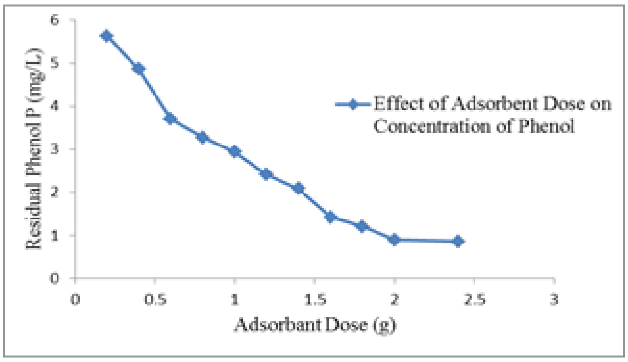

Fig. 02: Effect of Saw Dust (Dose) on Adsorption of Phenol

B. Effect of Contact time for adsorption of Phenol

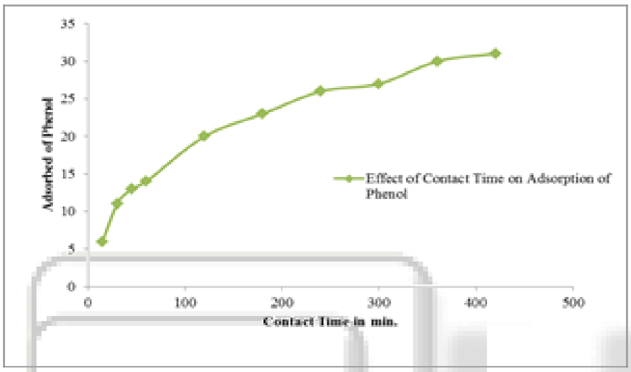

Fig. 03: Effect of Contact time for adsorption of Phenol

C. Adsorption Equilibrium Study

1) Langmuir isotherm

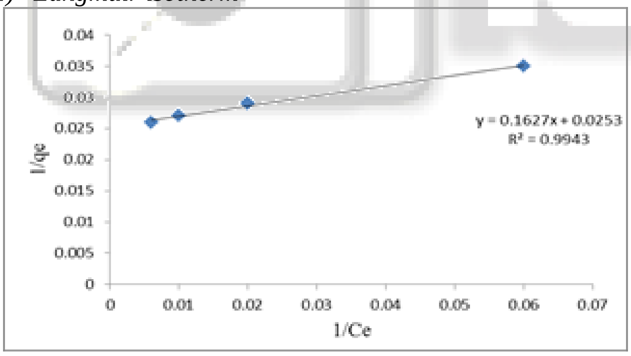

Fig. 04: Langmuir Isotherm plot of Phenol-Sawdust adsorption System

2) Freundlich Isotherm

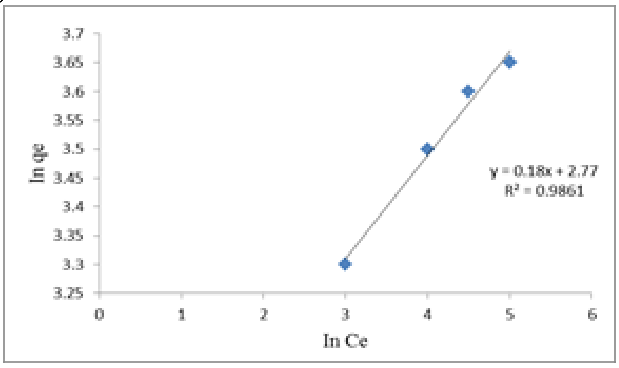

Fig. 05: Freundlich Isotherm plot of Phenol-Sawdust Adsorption System

3) Langmuir and Freundlich values for Saw Dust

Adsorbents	Langmuir values		Freundlich values	
	R^2	Equation	R^2	Equation
Sawdust	0.994	0.1627x + 0.025	0.9861	0.18x + 2.77

XV. CONCLUSION

Based on results of this project, Sawdust shows a great potential for removal of Phenol from wastewater. Including, response surface methodology was used to investigate the interactive effect of the operating parameters namely; adsorbent dose, initial concentration, solution pH etc.

The following conclusions can be drawn from the present work,

1) The optimal condition for Phenol-Sawdust system is found to be; Time=6 h, m= 2.0 gm/l.
2) From over all analysis of equilibrium model indicates the fitness of Langmuir Isotherm (R^2=0.994) to the Sawdust Adsorption system.
3) Phenol adsorption capacity of Sawdust was found to be increasing with increase in adsorbent dose up to a certain limit, latter on it decreases even increase in adsorbent dose

REFERENCES

[1] Aditi Gupta Removal of phenol from Wastewater using Mango Peel, International Journal of Engineering and technical Research (IJERT) ISSN:2321-0869, Vol. 1, Issue-9 November 2013.
[2] Arshad I. Esmael et.al. Adsorption of Heavy Metals from Industrial Wastewater using Palm Date Pits as Low Cost Adsorbent International Journal of Engineering and Advanced Technology (IJEAT) ISSN: 2249 – 8958, Volume-3, Issue-5, June 2014.
[3] ARRIS Sihem, et.al. Batch Adsorption of Phenol from Industrial Waste Water Using Cereal By-Products as A New Adsorbent, Energy Procedia 18 (2012) 1135 – 1144.
[4] A.V.V.S.SWAMY.et.al. International Journal of Engineering Research and Applications (IJERA) ISSN: 2248-9622. Vol. 2, Issue 4, July-August 2012, pp.262-265.
[5] Ahmad I. M., Batch adsorption of phenol onto physiochemical-activated coconut shell, Journal of Hazardous Materials, 161 (2009): pp.1522–1529.
[6] BULUT Yasemin et.al Removal of heavy metals from aqueous solution by sawdust adsorption Journal of Environmental Sciences 19(2007) 160–166, ISSN 1001-0742 CN 11-2629/X.
[7] Christina Rahe.et.al. International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 11, November 2014 ISSN (online): 2348 – 7550.
[8] C R Girish. et.al, Adsorption of Phenol from wastewater using locally available Adsorbents, Journal of Environmental Research And Development, Vol. 6 No. 3A, Jan-March 2012.
[9] Jadhav D N, Vanjara A K, "removal of phenol from wastewater using sawdust, polymerized sawdust and

sawdust carbon",Indian Journal of Chemical ,IJCT Vol.11, January 2004 .
[10] Hannafi N., Boumakhla M.A., Berrama T., Bendjama Z., Elimination of phenol by adsorption on activated carbon prepared from the peach cores: modelling and optimisation, journal of Desalination, 223 (2008): pp.264–268.
[11] Ihsan Habib Dakhi, "removal Of Phenol From Industrial Wastewater Using Sawdust", International Journal Of Engineering And Science, Vol.3,PP 25-31, May 2013.
[12] K. D. Harmayani et.al. Adsorption of Nutrients from Stormwater Using Sawdust International Journal of Environmental Science and Development, Vol. 3, No. 2, April 2012.
[13] Kennedy L. J., Vijaya J. J., Kayalvizhi K., Sekaran G., Adsorption of phenol from aqueous solutions using mesoporous carbon prepared by two-stage process, Chemical Engineering Journal, 132 (2007): pp.279–287.
[14] K. Saravanakumar et.al. Removal of phenol from aqueous solution by adsorption using zeolite African Journal of Agricultural Research Vol. 8(23), pp 2965-2969, 20 June 2013. DOI: 10.5897/Ajar11.194.
[15] L. Mukosha Development of Better Quality Low-Cost Activated Carbon from South African Pine Tree (Pinus patula) Sawdust: Characterization and Comparative Phenol Adsorption World Academy of Science, Engineering and Technology International Journal of Chemical, Nuclear, Materials and Metallurgical Engineering Vol:7, No:7, 2013.
[16] Larous. S.et.al. S. Energy Procedia 18 (2012):pp. 905 – 914.
[17] Mariangela Grassi .et.al. Removal of Emerging Contaminants from Water and Wastewater by Adsorption Process Springer Briefs in Green Chemistry for Sustainability, DOI: 10.1007/978-94-007-3916-1_2.
[18] Mehdi Shirzad-Siboni et. Al Removal of Phenol from Aqueous Solutions by Activated Red Mud: Equilibrium and Kinetics Studies Environ. Eng. Res. 2013 December,18(4) pp: 247-252 ISSN 1226-1025 eISSN 2005-968X.
[19] M.K.Dwivedi et.al. Adsorptive Removal of Phenol By Coal Fly Ash: Equilibrium And thermodynamic Studies International Journal of Advanced Technology in Engineering and Science Volume No.02, Issue No. 10, October 2014 ISSN (online): 2348 – 7550.
[20] M.T Uddin et. al. Adsorption Of Phenol From Aqueous Solution By Water Hyacinth Ash ARPN Journal of Engineering and Applied Sciences VOL. 2, NO. 2, APRIL 2007 ISSN 1819-6608
[21] Netai Muchanyereyi et.al. Adsorption of Phenol from Aqueous Solution Using Carbonized Maize Tassels British Journal of Applied Science & Technology 3(3): pp. 649-661, 2013.
[22] Obiora-Okafo Ifeoma A. et.al. Utilization of Sawdust (Gossweilerodendron balsamiferum) as an Adsorbent for the Removal of Total Dissolved Solid Particles from Wastewater, International Journal Of multidisciplinary Sciences And Engineering, Vol. 4, No. 4, May 2013.
[23] S. B. Divate, et.al Removal of heavy metal (phenol) by using various adsorbents International Journal of Scientific & Engineering Research, Volume 5, Issue 7, July-2014 ISSN 2229-5518, pp. 673-678.
[24] Somnath Mukherjee et. Al. Removal of phenols from water environment by activated carbon, bagasse ash and wood charcoal Chemical Engineering Journal 129 (2007) 133–142.
[25] Sunil J. Kulkarni, Ravi W. Tapre ,Suhas V. Patil ,Mukesh B. Sawarkar, "Adsorption of Phenol from Wastewater in Fluidized Bed Using Coconut Shell Activated Carbon", Procedia Engineering ,volume51, pp 300 – 307, 2013.
[26] S. Laxmi Gayatri.et.al, Assam University Journal of Science & Technology: Physical Sciences and Technology Vol. 5 Number II 156-166, 2010.
[27] Uttam Singh.et.al. VSRD International Journal of Technical & Non-Technical Research, Vol. 4 No. 3 March 2013 / 33 e-ISSN : 0976-7967, p-ISSN : 2319-2216.
[28] Ozkaya B., Adsorption and desorption of phenol on activated carbon and a comparison of isotherm models, Journal of Hazardous Materials, B129 (2006): pp.158-163.

