8. Adsorptive Removal of Phenol from Wastewater by Crushed Brick Powder: Influence of System Parameters

Pradyumna Ghosal

Department of Applied Chemistry and Basic Sciences,
Sardar Bhagwan Singh University, Dehradun, Uttarakhand

Sujata Brahma, Mehdi Al Kausor

Department of Chemistry, Science College,
Kokrajhar, Assam, India.

Abstract:

The aim of this work was to study the removal of phenol from wastewater by adsorption using raw and chemically treated with calcined brick powder due to its efficiency, high adsorption capacity and low operational cost adsorbent. Sample was characterized by collecting red bricks from our locality under Dhubri district, Assam, crushed them by a hammer and then grounded to fine powder. It was then washed, soaked overnight with distilled water and dried.

Powder X-ray Diffraction (PXRD) and X-Ray Fluorescence (XRF) Spectra analysis were used to determine adsorbent features. PXRD spectra of brick powder strong peaks at 2Θ *values of* 21^{O}, 27^{O} *and* 50^{O} *are characteristic peaks of quartz and small peaks at* 27^{O} *indicate presence of albite and peaks at* 33^{O} *and* 35^{O} *indicate presence of hematite. XPS spectra indicated the constituents of brick powder were SiO2 (56.32%), Fe2O3 (27.67%), K2O (8.88%), MgO (3.17%) and TiO (2.98%). The concentration of the dye/phenol was analyzed with the help of a UV-visible spectrometer and the kinetic data by using Lagergren pseudo first-order model.*

The absorptive capacity is carried out at equilibrium time. The experimental results show that adsorptive yield decreases from 52.5% to 30.5% with an increase in the adsorbent dose varying concentration (10gL-1 to 25gL-1). The absorbent showed highest removal of 52.5% with contact period of 240 minutes. On the other hand, the influence of initial concentration of phenol was studied by taking catalyst load of 10gL-1, this shows that on increasing the initial concentration of phenol from 5-25ppm, the percentage removal decreases from 54% to 33.8% at equilibrium time of 240 minutes

Keywords:

Adsorption; Phenol; Brick Powder; Kinetics; Lagergren pseudo first-order model

8.1 Introduction:

Phenols was discovered by Friedlieb Ferdinand Runge in the year 1834, it was extracted (in impure form) from the coal tar. Runge called phenol “karbolsaure” (coal-oil-acid). Coal tar remained the primary source until the development of the petrochemical industry. In 1841, the French chemist named Auguste Laurent obtained phenol in pure form. In the year 1836, Auguste Laurent innovated the name “phene” for benzene, this is the root of the word “phenol” and “phenyl”. In the year 1843, A Freanch chemist Charles Gerhardt innovated the name “Phenol”. Phenolic compounds are very pernicious environmental pollutants. The phenol synthetic is a basic structural for a varity of organic compounds. Phenolic compounds are commonly use in the factories of plastic, dyes, drugs, petrochemicals for manufacturing perposes. The wastewater of many chemical plants, industries, pesticides and dye manufacturing industries containing phenols which is very much harmful to human civilization and aquatic animals.

Now a days Phenolic compound is a very dangerous environmental pollutants and it is also a potential cause of human cancer (Ding et al., 2014). Phenols and its derivatives are widely used as a resource or raw material in many industries such as petroleum, petrochemicals, wood, plastic, textile, rubber, dye, pesticide, industries, and many more, the waste water of these industries are discharge into waterbodies (An et al., 1989). This is a cause of water pollution. the presence of environmental organic micropollutants an poisonous interest, among which substituted phenols play an important role. due to toxicity, stability and biological systhesis animals and human being are being unhealthy for health.

The phenolic compound named as xylenols, as well as many polyhydric phenols which decharge from the industries of coal tar and plastc, dye, are very dangerous for health. In the agriculture field, phenolic compound is employed as herbicides (Devi and Gnudi, 1989). The wastewater which contains phinolic compound can cause of protein degradation, central nervous system damage, kidney problem ect on the human body. The Environmental Protection Agancy (EPA) has listed phenolic compound on the priority pollution list. The waster which contains phenolic compound going to impure the surface water as well as ground water so it is necessary to remove phenolic pollutants from wastewaters before discharge into water. There are so many techniques and method have been invernted or developed to remove phenol from wastewater including distillation, chemical oxidation, electrochemical, extraction and adsorption (Villegas et al., 2016).

The techniques or the methods are such as –

1. Absorbtion
2. Oxidation with ozone/hydrogen peroxide
3. Biological method
4. Membrane filtration
5. Ion exchange
6. Electrochemical oxidation
7. Reverse osmosis
8. Photocatalytic degradation

Between these technologies adsorption is most common and widely used method. Adsorption is the best method to remove the phenolic compound at low cost with great advantage. There is also different method of adsorption such as adsorption with banana peels, with zeolite, with activated carbon, with clay, with brick powder. Among these adsorptions with **calcined** brick powder is the most preferred process due to its efficiency, high adsorption capacity and low operational cost.

Vazquez et. al., 2017 removal of phenols and its derivative from the coke wastewater by the method of adsorption was studied. The used adsorbent for the adsorption method is Granular Activated Carbon and the resins XAD-2, AP-246 and OC-1074. Equilibrium, kinetics and column assays are performed, fitting the equilibrium data to Langmuir and Freundlich model and kinetic data from the Lagergren equation. The best result was found from the GAC, which give highest adsorption capacities. In the equilibrium assays the resultant adsorption capacities (*Q*) gives 1.48 mg g−1 for GAC, 0.07 mg g^{-1} for resins AP-246 and 0.04 mg g^{-1} for OC-1074. In the kinetic assays, the values of the Lagergren adsorption parameter, *q*e, were 1.69, 0.15 and 0.14 mg g^{-1} for GAC, AP-246 and OC-1074, respectively and in the column assays, the dynamic capacity of GAC for up to 480 bed volumes was 1.82 mgmL−1. No saturation was found for this volume due to the asymptotic shape of the breakthrough curve, whereas for the same percolated volume, the resins AP-246 andOC-1074 were saturated. These two resins presented similar saturation capacities of around 1.1 mg mL^{-1}

Ahmaruzzaman et al., 2005 states that the possible use of coal, residual coal, and residual coal reacated with H_3PO_4 as a way to of removal of phenol from wastewater of the industries the research was consciousness using batch experiments, with synthetic wastewater having phenol concentration of 1000 ppm. In this research petroleum coke, coke breeze, rice husk, and rice husk char are have been used as a low-cost adsorbent. The effect of system variables such as pH, contact time, and temperature has been diagnosed. The suitability of the Freundlich, Langmuir, and Redlich–Peterson adsorption models to the equilibrium data was diagnosed for each phenol–adsorbent system. At last, he found that the model of Redlich–Peterson is best for the equilibrium data for all the phenol–sorbent systems. The Lagergren first-order rate expression was used for kinetic modeling of removal of phenols. To determine the breakthrough curves, a series of column experiments were performed.

Achak et al., 2009 main cause of this research was to determine the application of banana peel as a low-cost adsorbent of removing of phenol and its derivative from the wastewater of olive mill. in this research the effect of adsorbent dosage, pH and contact time were diagnosed. The models of Freundlich and Langmuir adsorption were used for mathematical description of the adsorption equilibrium and it is shown that the experimental result is fit for both of the model. Desorption studies result that low pH value was efficient for desorption of phenolic compounds. This result showed that we can use banana peel as a low cost biosorbent and the result of the adsorbent is very good.

Gil et. al.,2011 Here by intercalation of solutions of aluminium and zirconium and evaluated as adsorbents for the removal of Orange II and Methylene Blue from aqueous solutions two pillared clays are synthesized. The maximum adsorption was shown to be 300 min. Both clays were found to have the same adsorption capacity. In terms of pseudo-first- and -second-order kinetics, and the Freundlich, Langmuir the adsorption kinetics of dyes has been studied and to the equilibrium adsorption data the Sips isotherm models have also been applied. To increase the adsorption capacities of the two pillared clays for Orange II , addition of NaCl is found .

Koubaissy et al., 2008 has worked on Adsorption and Competitive Adsorption on Zeolites of Nitrophenol Compounds Present in Wastewater of various industries to study here to the removal of various nitrophenolic compounds such as *ortho*-nitrophenol, *para*-nitrophenol, *meta*-nitrophenol and 2,4-dinitrophenol from aqueous solution using hydrophobic FAU zeolites. Using the Fowler-Guggenheim equation the adsorption equilibrium of nitrophenols from aqueous solutions by FAU can be well-described. The order of sorption capacity is: ONP > 2.4-DNP > PNP > MNP. The result of the research is that hydrophobic FAU zeolite is the best adsorbent.

In another work, Koubaissy et al., 2011 used four kinds of different zeolites as adsorbents for removal of phenol and properties were compared to that of an activated carbon. Contaminant in this investigation was the phenol diluted in water and the adsorption was carried out in batch and continuous flow. To remove phenol molecules adsorbed, BEA zeolite was generated under air flow at 400˚C with a rate of 2˚C min^{-1}. In comparison to an activated carbon, the adsorption capacity was slightly higher at low phenol concentration (1.6 g/L).

Djebber et al., 2012 employed natural clay was employed as an adsorbent by him for the removal of phenolic compounds from aqueous solutions. Study of parameters such as pH solution, temperature, contact time and initial phenol concentration had been done. 100 mg of adsorbent and 100 mL of phenol solution at different initial concentrations of phenol at 23˚C were used for the adsorption experiment. Approximately 60-70% of phenol was removed by the activated and natural clay after the contact time of 5h. Improvement of the adsorption of phenol onto natural clay was made by the process of activation. With the increase in temperature, the adsorption capacity of phenol was decreasing. The data of adsorption equilibrium were suitable for both Freundlich and Langmuir isotherm.

Strachowski et al., 2015 studied the removal of phenol, 2-Chlorophenol and 4-Chlorophenol from aqueous solutions using activated carbon, multiwalled carbon nanotubes and carbon-encapsulated iron nanoparticles (CEINs). For different materials, the surface area was found to be 1187, 156 and 36 m^2/g for AC, MWCNTs and CEINs respectively. 150 mg/L initial concentration of the phenolic compounds and the relation of adsorbent mass and solution volume of 0.5 g/L were used for the adsorption experiments. The maximum adsorption capacity was obtained for AC followed by MWCNTs and CEINs in order. However, the maximum adsorption kinetic rate was found in MWCNTs followed by CEINs and (549.5 mg/g).

Viaraghavan et al., 1998 studied the removal of phenolic compounds from wastewater using fly ash, peat and bentonite. The adsorption of phenol on peat and bentonite was well described by the Freundlich isotherm while the adsorption of phenol on fly ash, peat and bentonite described by the Langmuir isotherm were found to adsorb 46.1, 41.6 and 42.5% of phenol respectively from an initial concentration of approximately 1 mg/L. Jain and Bhatnagar, 2012 also studied the removal of methyl phenol from aqueous solution by adsorption on blast furnace sludge, dust and slag. The use of some carbonaceous adsorbents prepared from fertilizer industry has also been made for the removal of methyl phenol. Batch method studied the adsorption on this adsorbent as a function of contact time, concentration and temperature. The report showed that the adsorption is endothermic. The experimental data obeys the Langmuir equation and analysis indicates that the adsorption was a first order process.

Aksu et al., 2001 also studied the removal of monochlorinated phenols from wastewater by dried activated sludge and fly ash. For the mathematical description of adsorbent equilibrium, the Freundlich, Langmuir and Redlich-Peterson adsorption models were used and the report showed that the experimental data fit well to Redlich-Peterson model within the concentration range.

Mandi et al., 2009 The adsorption of phenolic compounds from olive mill wastewater (OMW) has been investigated as a function of adsorbent dose, pH and contact time. The results showed that the increase in the banana peel dosage from 10 to 30 g/L significantly increased the phenolic compound adsorption rates from 60 to 88%. Increase in the pH above neutrality resulted in the increase in the phenolic compound adsorption capacity. The adsorption process was fast, and it reached equilibrium in 3h contact time. The equilibrium process was described well by the Langmuir and Freundlich isotherm models with maximum sorption capacity of 688.9 mg/g of phenolic compounds on banana peel at 30°C. Banana peel, an inexpensive and easily available material, can be an alternative to more costly adsorbents used for the removal of phenolic compounds from olive mill wastewater (OMW).

The aims and objectives of this research work are as follows

- **(i)** **Preparation of the Material**: To obtain and prepare crushed brick powder (CBP) by collecting red bricks from our locality. The CBP after some modification will be used as low-cost adsorbent.
- **(ii)** **Characterization**: To characterize the material by Powder X-Ray Diffraction (PXRD), Scanning Electron Microscopy (SEM), X Ray Fluorescence (XRF), FT Infra-Red (FT-IR)
- **(iii)** **Application of the Material**: To use the material as adsorbent for removal of some phenolic compounds from wastewaters. The kinetic study of the adsorption to be studied by changing various parameters and various models will be applied. The maximum percentage removal/adsorption capacity of the material to be determined.

8.2 Experimental Section:

Preparation of the Materials: The crushed brick powder (CBP) was obtained by collecting red bricks collected from Bahalpur, Assam under Dhubri District. The samples were crushed by a hammer and then grounded with a householder grinder followed by mechanical sieves to obtain six the adsorbent with varying particle sizes. The material was grounded to fine powder and washed with distilled water for several times followed by after soaking it in distilled water for overnight. The material was filtered and dried in hot air oven at 80°C

Characterization:

The adsorbents were characterized by Powder X-Ray Diffraction (PXRD) and X Ray Fluorescence (XRF) Spectra analysis. PXRD, XRF analysis were done at CECRI, Karaikudu, Tamilnadu, India.

8.3 Adsorption Study:

The batch adsorption study was carried out by mixing a fixed amount of the adsorbent with a constant volume of solution containing the phenolic pollutant in Erlenmeyer flasks in a constant temperature water bath thermostat shaker for a known time interval under dark. The unadsorbed supernatant liquid was analysed with the help of a UV-Visible spectrometer.

The kinetic study of the adsorption was studied by changing various parameters and various models will be applied. The maximum percentage removal/adsorption capacity of the material was determined.

Characterization of the Material:

Characterization by Powder XRD:

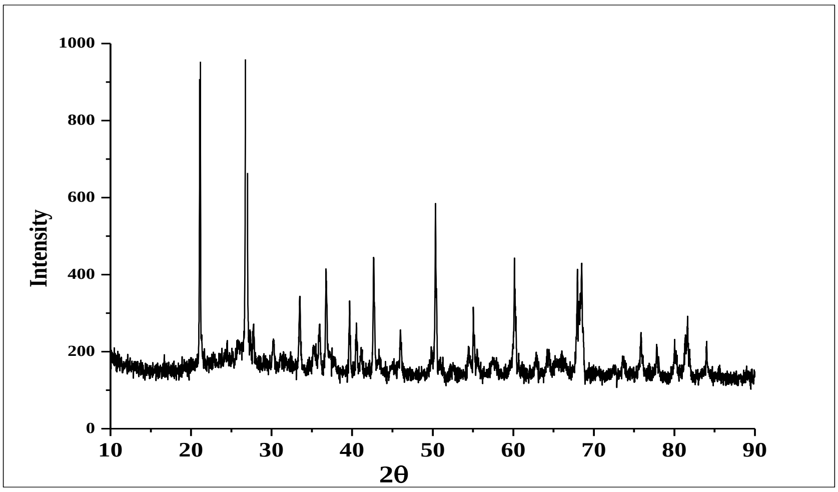

Figure 8.1: PXRD spectra of Brick Powder

PXRD spectra of Brick Powder (Figure 8.1) strong peeks at 2ϴ values of 21°, 27° and 50° are characteristic peeks of quartz (JCPDS code 30444). Small peeks at 27° indicate presence of albite (JCPDS code 90466) and peeks at 33° and 35 ° indicate presence of hematite. Treating WB with a concentration of acid (A2-WB sample), did not alter the mineralogical composition, and PXRD patterns similar to untreated WB were obtained (not shown).

Characterization by X-Ray Fluorescence Spectra (XPS):

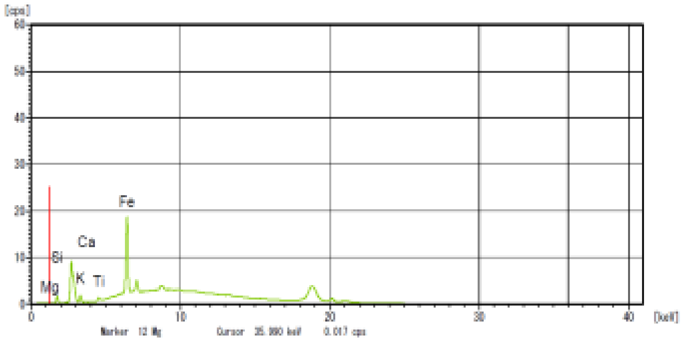

Figure 8.2: XRF Spectra of Brick Powder

Table 8.1: XRF Spectra analysis

Elem.	Line	Mass [%]	2sigma [%]	Atomic [%]	Intensity[cps/mA]	Formula	Mass [%]	Molecule [%]
12Mg	K	1.912	9.837	1.844	0.11	Mg0	3.170	5.876
14 Si	K	26.326	4.502	21.975	20.79	Si02	56.317	70.037
19 K	K	7.373	1.366	4.422	22.31	K20	8.882	7.046
20 Ca	K	0.698	0.315	0.408	2.61	Ca0	0.976	1.301
22 Ti	K	1.790	0.415	0.876	11.97	Ti02	2.985	2.792
26 Fe	K	19.353	3.347	8.125	274.96	Fe203	27.670	12.948
8 0		42.548	8.394	62.351				

The chemical analysis as studied by taking the XRF spectra (Fig.8.2) which indicated that the main constituent of WB was silica SiO_2 (56.32%), in addition to smaller amounts of other oxides, such as iron oxide Fe_2O_3 (27.67%), K_2O (8.88 %) MgO (3.17%) and TiO (2.98%) (Table 8.1)

Adsorption study: The batch adsorption was carried out by mixing a fixed amount of the catalyst with a constant volume of solution containing the pollutant in 100 mL Erlenmeyer flasks in water bath thermostat shaker maintaining a constant temperature. The flasks with the dye solutions were shaken for a known time interval in dark until eqquillibrum was achieved. The unadsorbed supernatant dye was centrifuged by a centrifuge machine and the concentration of the dye was analysed with the help of a visible spectrometer. The adsorption capacity of the composites at a particular time interval were calculated by using the following equation

$$q_t = [(C_o - C) x V]/w \text{ .... } (1)$$

Where C_0 and C_t are the initial concentration and concentration of the dye/phenol solution at time t, w is the amount of the catalyst in g and V is the volume of the solution in L.

Adsorption kinetics: The adsorption of the dyes was studied by using Lagergren pseudo first-order model (Lagergren, 1898; Ho, 2004):

$$\log(q_e - q_t) = \log(q_e) - (k_1/2.303)t \text{ .... (2)}$$

where, q_e and q_t are the amounts adsorbed per unit mass at equilibrium and at any time t, k_1 is the first order adsorption rate constant.

8.4 Result and Discussion:

8.4.1 Influence of Catalyst Load on Adsorption of Phenol:

The influence catalyst dose of phenol is studied by taking 10 ppm of initial phenol concentration with a varying catalyst load from 10 g/L to 25 g/L and the results are shown on Table.8.2 below.

Table 8.2: Effect of catalyst dose

Time (min)	Mass of Adsorbent (g/L)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
60	10	8.5	1.5	0.15	15
120	10	7.2	2.8	0.28	28
180	10	5.25	4.75	0.475	47.5
240	10	4.75	5.25	0.525	52.5

Time (min)	Mass of Adsorbent (g/L)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
60	15	8.8	1.2	0.12	12
120	15	7.6	2.4	0.24	24
180	15	6.1	3.9	0.39	39
240	15	5.85	4.15	0.415	41.5

Time (min)	Mass of Adsorbent (g/L)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
60	20	8.8	1.2	0.12	12
120	20	7.6	2.4	0.24	24
180	20	6.1	3.9	0.39	39
240	20	5.85	4.15	0.415	41.5

Time (min)	Mass of Adsorbent (g/L)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
60	25	9.2	0.8	0.08	8
120	25	8.5	1.5	0.15	15

Time (min)	Mass of Adsorbent (g/L)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
180	25	7.25	2.75	0.275	27.5
240	25	6.95	3.05	0.305	30.5

It is observed that he percentage removal of phenol is decreased from 52.5 % to 30.5% on increasing the catalyst dose from 10 g L^{-1} to 25 gL^{-1} after 240 min. The highest percentage adsorption (52.5%) is obtained with a catalyst load of 10 g L^{-1}. Figure 8.3 depicts the plot of removal of phenol with different doses of the material at Equilibrium time.

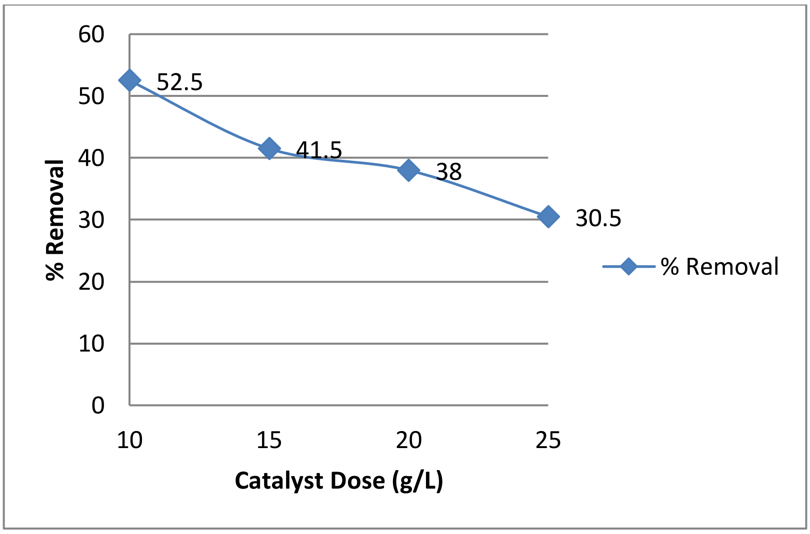

Figure 8.3: Plot of removal of phenol with different doses of the material at Equilibrium time

The higher amount of the composite provided more surface for the dye to get adsorbed on it and consequently an increase in adsorption efficiency should be observed. However, it was observed that increase of adsorbent dose after an optimum dose the percentage removal decreases. This may be due to particle agglomeration (Simakov and Tsur, 2007).

8.4.2 Influence of Initial Concentration on Adsorption of Phenol:

The influence initial concentration of phenol is studied by taking a catalyst load of 10 g/L and varying the initial concentration of phenol from 5 ppm to 20 ppm and the results are shown on Table. 8.3 below.

Table.8.3 Influence of Initial Concentration on adsorption of phenol

Initial Conc. (C_0)	Time (min)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
5 ppm	60	4.1	0.9	0.18	18
5 ppm	120	3.8	1.2	0.24	24
5 ppm	180	3.25	1.75	0.35	35
5 ppm	240	2.3	2.7	0.54	54

Initial Conc. (C_0)	Time (min)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
10 ppm	60	8.5	1.5	0.15	15
10 ppm	120	7.2	2.8	0.28	28
10 ppm	180	5.25	4.75	0.475	47.5
10 ppm	240	4.75	5.25	0.525	52.5

Initial Conc. (C_0)	Time (min)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
15 ppm	60	17.2	2.8	0.14	14
15 ppm	120	15.1	4.9	0.245	24.5
15 ppm	180	13.45	6.55	0.3275	32.75
15 ppm	240	12.55	7.45	0.3725	37.25

Initial Conc. (C_0)	Time (min)	Eq. Conc (Ct)	(C_0 - Ct)	(C_0 - Ct)/C_0	% Removal
20 ppm	60	22.8	2.2	0.088	8.8
20 ppm	120	20.2	4.8	0.192	19.2
20 ppm	180	17.75	7.25	0.29	29
20 ppm	240	16.55	8.45	0.338	33.8

The plot of % removal with different initial concentrations (Figure 8.4) with a catalyst load of 10 g L^{-1} shows that on increasing the initial concentration of phenol from 5 ppm to to 25 ppm, the percentage removal decreases from 54% to 33.8% at equilibrium time of 240 minutes.

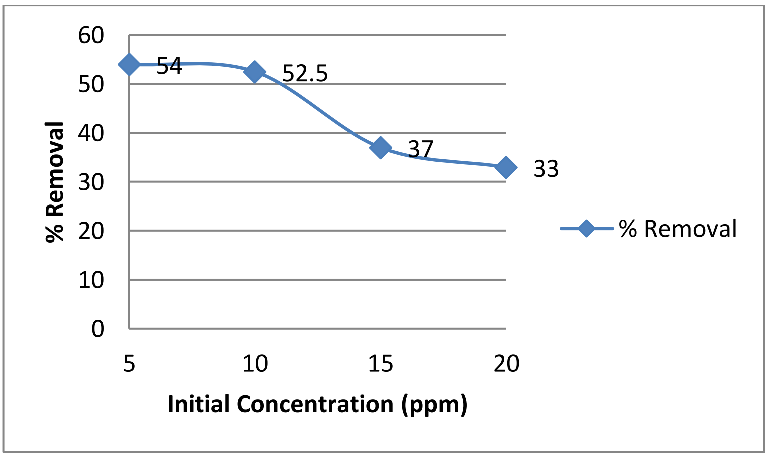

Figure 8.4: plot of % removal with different initial concentrations

The decrease in the percentage adsorption can be explained by the fact that as the concentration of the dye increases, the ratio of the number of dye particles to the active sites of the composite goes on increasing which prevents the composite to adsorb further dye particles onto the surface-active sites (Sarma et al., 2011).

8.4.3 Adsorption Kinetics:

The adsorption of the phenol was studied by using Lagergren pseudo first-order model (Lagergren, 1898; Ho, 2004):

$$\log(q_e - q_t) = \log(q_e) - (k_1/2.303)t \text{ .... (4)}$$

where, q_e and q_t are the amounts adsorbed per unit mass at equilibrium and at any time t, k_1 is the first order adsorption rate constant. For different catalyst doses, the plots of log (qe – qt) vs. t (Fig. 8.5) are found to be linear. The first order rate constants (obtained from the slopes) decrease from $16.12\text{x}10^{-3}$ min^{-1} to $6.0\text{x}10^{-3}$ min^{-1}. Similarly for different initial concentration of phenols, the plots of log (qe – qt) vs. t (Figure 8.6) are also found to be linear. The first order rate constants (obtained from the slopes) decrease from $18.4\text{x}10^{-3}$ min^{-1} to $11.5\text{x}10^{-3}$ min^{-1} min^{-1}

Table. 8.4: Lagergren first order rate constants for adsorption of Phenol

Catalyst dose	**First order kinetic equation**	**Lagergren rate constant (k_1) (min^{-1})**	**R^2**
10 g/L	$\log(q_e - q_t)=\log q_e-0.007t$	16.12×10^{-3}	0.902
15 g/L	$\log(q_e - q_t)=\log q_e-0.006t$	13.8×10^{-3}	0.948
20 g/L	$\log(q_e - q_t)=\log q_e-0.004t$	9.2×10^{-3}	0.948
25 g/L	$\log(q_e - q_t)=\log q_e-0.003t$	6.0×10^{-3}	0.978
Initial oncentration	First order kinetic equation	Lagergren rate constant ($k_1\text{x}10^{-3}$) (min^{-1})	R^2
5 ppm	$\log(q_e - q_t)=\log q_e-0.008t$	18.4×10^{-3}	0.834
10 ppm	$\log(q_e - q_t)=\log q_e-0.007t$	16.12×10^{-3}	0.902
15 ppm	$\log(q_e - q_t)=\log q_e-0.006t$	13.8×10^{-3}	0.953
20 ppm	$\log(q_e - q_t)=\log q_e-0.005t$	11.5×10^{-3}	0.952

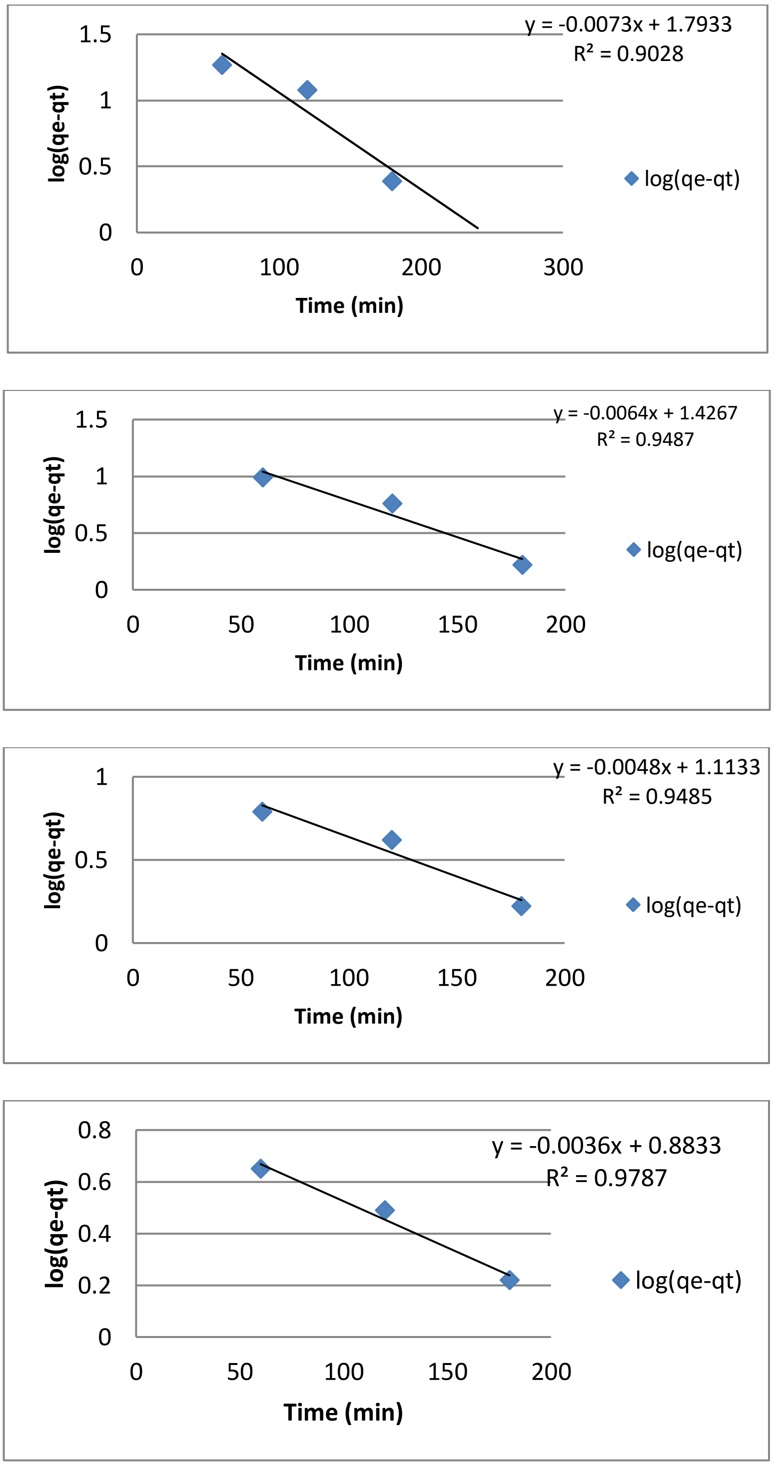

Figure 8.5: Lagergren plots of log (qe-qt) against time (min) with initial phenol concentration 10 ppm and Catalyst load = 10-25 gL^{-1}

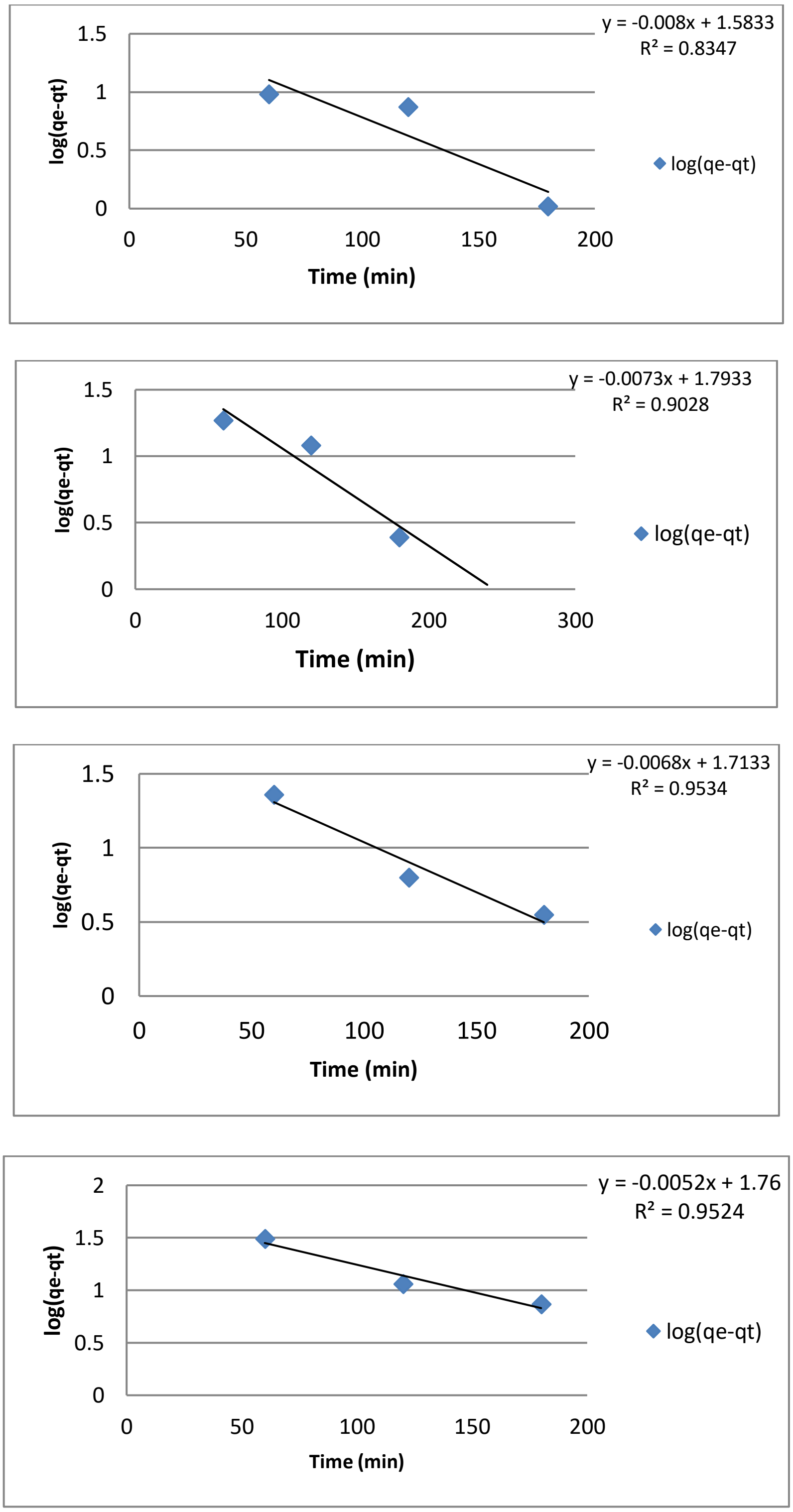

Figure 8.6: Lagergren plots of log (qe-qt) against time (min) with initial phenol concentration from 5 ppm to 20ppm and Catalyst load = 10 gL^{-1}

8.5 Conclusion:

In this study, brick powder is used as new adsorbents for removal of phenol from waste water. The adsorption method was very simple and had shown great potential for removal of phenol. The main conclusions that can be drawn from the above study are given below:

1. Adsorption of phenol was influenced by adsorbent dose, initial phenol concentration and solution pH. The adsorbent showed highest removal of 52.5% with the contact period of 240 min and a dose of 10 g/L. On increasing the intial concentration, the % removal decreses. The highest % removal of 54% was obtained with an initial concentration of 5 ppm of phenol. The influence of solution pH could not be studied due to lack of time.

2. The adsorption followed the Lagergreen pseudo first order kinetic model. The highest rate constant of 16.12 x 10^{-3} min^{-1} was obtained with a catalyst dose of 10g/L at an initial concentration of 10 ppm phenol. Again, highest rate constant of 18.4 x 10^{-3} min^{-1} was obtained with a catalyst dose of 10g/L at an initial concentration of 5 ppm phenol.

3. The chemical treatment of brick waste may affect its removal properties. Therefore, further investigation in this area is suggested.

8.6 References:

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