Removal Characteristics of Benzene Aromatic Organic Compound from Aqueous Solution by Soil

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ABSTRACT

Adsorption technique is widely used for removal of toxic organic contaminants from aqueous streams. Although commercial activated carbon is an effective adsorbent, it's widespread used is restricted due to its high cost and substantial lost during regeneration. The aim of this study is to investigate the possibility of soil as an alternative adsorbent for Benzene aromatic organic compound removal from aqueous solution .The removal characteristics of benzene, nitrobenzene, clorobenzene, bromobenzene, from aqueous solution by soil were investigated under various conditions of contact time, particle size, pH, concentration and temperature. The adsorption kinetics and isotherms were analyzed to understand the sorption behavior and mechanisms involved in benzene uptake by soil particles. The experimental results underlined the potential of soil for recovery of benzene, nitrobenzene, clorobenzene, bromobenzene from waste water. The main mechanisms involved in the removal of benzene, nitrobenzene, clorobenzene, bromobenzene from solution by soil. It was found that these low cost soil adsorbent demonstrated good removal capability of benzene, nitrobenzene, clorobenzene, bromobenzene and hence can be used economically on large scale. Overall, this study provides valuable insights into the potential application of soil as an effective and sustainable remediation approach for benzene-contaminated aqueous environments. Understanding the removal characteristics and mechanisms of benzene adsorption by soil is essential for developing efficient remediation strategies to mitigate benzene pollution and protect environmental and human health.

Key Words:- soil, benzene, nitrobenzene, clorobenzene, bromobenzene, adsorption, kinetics, mechanism.

INTRODUCTION

Benzene, a ubiquitous aromatic hydrocarbon, is a well-known environmental pollutant due to its widespread industrial use and presence in petroleum products. Despite its industrial importance, benzene poses significant risks to both the environment and human health due to its toxicity and carcinogenicity [1].

The contamination of soil and water with benzene is a major concern worldwide, prompting the need for effective remediation strategies to mitigate its adverse effects. Various methods have been explored for the removal of benzene from aqueous environments, including physical, chemical, and biological approaches. Among these, adsorption by soil has emerged as a promising and environmentally sustainable method for benzene remediation [2]. Soil, as a natural sorbent, possesses inherent properties that facilitate the adsorption of organic contaminants such as benzene. The adsorption process involves the accumulation of benzene molecules onto the surface of soil particles through physical and chemical interactions [3-4]. Soil properties such as organic matter content, mineral composition, surface area, and porosity play crucial roles in determining the adsorption capacity and efficiency of benzene removal. Understanding the removal characteristics and mechanisms of benzene adsorption by soil is essential for optimizing remediation strategies and ensuring effective pollutant removal. By comprehensively understanding the removal characteristics of benzene by soil, this study contributes to the development of sustainable remediation technologies for benzene-contaminated environments. Implementing soil-based remediation approaches not only offers an effective means of pollutant removal but also promotes the utilization of natural resources in environmental protection efforts. The removal of benzene, an aromatic compound, from aqueous solutions by soil involves several mechanisms such as adsorption, biodegradation, and volatilization. Soils, with its complex matrix of organic and inorganic components, can effectively removal benzene from water. Various industrial wastes and agricultural materials such as paper mill sludge, coal, dried sewage waste, green macro alga, and rice husk ash and coal flyash, soil have been explored for their technical visibility to remove. Soil has been the most widely used adsorbent for organics removal from aqueous phase. The activated carbon adsorption is highly expensive. Soil is cheap and locally available adsorbent and it is found in abundance in India and is one such material and can be an alternative to active carbon. The present studies have been conducted to investigate the effect of system variables, particle size of adsorbent, pH of adsorbate, initial adsorbate concentration and temperature of the system on the kinetics of benzene[12-14,] nitrobenzene, clorobenzene, bromobenzene, adsorption on soil produced from thermal power plant.. The applicability of kinetic models, the pseudo-first order models of Lagergren, is analyzed by estimation of the corresponding rare parameter and correlation coefficients.

Aims And Objectives:-

The present study is undertaken with the following objectives

1. To compare the performance and effectiveness of the adsorbents in removing benzene, nitrobenzene, clorobenzene, bromobenzene, by adsorption from wastewater.
2. To determine the effect of size, pH, conc. and temperature on adsorption process.
3. To examine the adsorption rate constant to study the application of pseudo first order (Lagergren) rate equation

MATERIAL AND METHODS

Standard benzene, nitrobenzene, clorobenzene, bromobenzene, solutions are prepared (500 mg/L) by weighing the purified grade chemical and dissolving them in minimum volume of acetone. Portion of this solution is diluted with distilled water similar to those of real waste-water sample. All reagents are of A.R.grade. Experimental solutions of desired concentration are prepared by successive dilution. Soil characterization is performed with a number of experimental approaches to investigate all relevant features. Soil is obtained from the land of Balaghat in the Lohara district of Madhya Pradesh. The sample is then divided into different fractions of different particle sizes using a standard by sieve of lattice size having a geometric mean particle diameter of 75µm. After that, the 75µm fraction of the sample was divided, providing samples for XRF, XRD, and SEM analysis. The chemical constituents and LOI at 800 °C were determined by the Indian Standard Method (Indian Standard Methods of Chemical Analysis of Fireclay and Refractory Materials 1960), the specific gravity, surface area and porosity and are shown in Table-1.The chemical compositions of fractions of soil are also determined by Indian Standard methods[8] and are shown in Table-2. The result indicate that silica and –alumina oxide are the major constituents of soil. The chemical analysis of data indicates that the sample consists of mullite ($Al_6Si_2O_{13}$), quartz (SiO_2), magnetite (Fe_3O_4), anhydrite ($CaSO_4$), hematite (Fe_2O_3), and lime (CaO) as the major phase. These fractions are used in batch kinetic experiment without any pretreatment. Batch kinetics adsorption experiment is conducted by shaking 25ml of benzene , nitrobenzene, clorobenzene, bromobenzene solution with 1g of soil fraction in100 ml Conical glass Stoppard flask (to avoid Vaporization losses of benzene , nitrobenzene, clorobenzene, bromobenzene at particle sizes (75µm), pH (6.5), concentration of benzene , nitrobenzene, clorobenzene, bromobenzene (500mg/L) and temperature(30,^{0}C) using thermostatic shaker at 200 rpm(similar to environmental condition) .The sample are covered during the entire experiment to avoid benzene[9-11] , nitrobenzene, clorobenzene, bromobenzene degradation by photolysis. The pH of solution is adjusted with HCl or NaOH by using pH meter. The progress of sorption is determined by centrifuging the sorbate-sorbent solution at predefined intervals of time and analyzes the supernatant liquid using UV-1800 Shimadzu UV- Spectrophotometer by monitoring the absorbance changes at a maximum wavelength of 255 nm,252nm,254nm,250nm. It should be noticed that below 250 nm the absorption band is not specific to Benzene compound because a lot of organic compounds have an absorption in their spectral windows. Each experiment is performed at least under identical conditions.

RESULTS AND DISCUSSION

Kinetic Models

In order to investigate the kinetics[5-6] of adsorption of benzene, nitrobenzene, clorobenzene, bromobenzene on soil, the constants of adsorption were determined in terms of the pseudo-first order models. The pseudo-first order equation was first represented by Lagergren

$$\textbf{Log}\ (q_e\text{-}q_t) = \log q_e - k\,t/2.303\text{----------------------}\ (1)$$

Where q_t (mg g^{-1}) is the amount of organic compound adsorbed at time t, q_e (mg g^{-1}) is the amount adsorbed at equilibrium and k is equilibrium rate constant of adsorption. The corresponding linear plots of log(q_e-q_t) versus t depicted in **Fig. 1.2, 1.4, 1.6** and 1.**8** for adsorption of benzene , nitrobenzene, clorobenzene, bromobenzene on soil under different conditions indicate the validity of applying equation (1) to the system known as Lagergren equation and relates to a pseudo first -order sorption process. The value of rate constant k, for adsorption of benzene, nitrobenzene, clorobenzene, bromobenzene on soil under different condition are calculated from the slopes of these plots and are given in **Table 3**.

Effect of Particle Size

The effect of particle size of kinetics[7] of benzene, nitrobenzene, clorobenzene, bromobenzene on soil is studied. The experimental kinetic curves are presented in **Fig 1.1**.The experimental data are described by pseudo-first-order model and are given in **Table 3** as calculated from linear plots of **Fig. 1.2**.The silica and alumina contents of soil play a major role in the sorption of benzene, nitrobenzene, clorobenzene, bromobenzene.

Effect Of Ph

The experimental kinetic curves are presented in **Fig1.3**. The pH values used in this study are 6.5, for the sorption of benzene, nitrobenzene, and clorobenzene, bromobenzene on soil. The experimental results are described by the pseudo-first order rate constant, k, of sorption at various pH values (determined from the linear plots of **Fig. 1.4**) and are listed in table 3. The removal of benzene, nitrobenzene, clorobenzene, bromobenzene from aqueous solution to soil which can be represented as:

$$\mathbf{H_2O + M^+ \xleftarrow{H^+} MOH \xrightarrow{OH^-} MO^- + H_2O}$$

Effect Of Concentration

The effect of concentration on kinetics of benzene, nitrobenzene, clorobenzene, bromobenzene on soil is investigated. **Fig.1.5** presents the experimental kinetics curve with benzene, nitrobenzene, clorobenzene, bromobenzene concentration in the range 500 mg/L. Obviously the increase in concentration of the solution leads to a decrease in the sorption rate constant. From the plot **(Fig. 1.5)** it could be seen that equilibrium is established after 120 minutes from the beginning of the process. The experimental results are described by the pseudo-first-order model of Lagergren **(Fig. 1.6)** and from this the rate constants are calculated.

Effect Of Temperature

The sorption experiments are conducted at temperatures in the range 30°C with soil **(Fig.1.7)** which shows that adsorption rate constant increases with increasing temperature shown in **Table 3(**calculated from **Fig.1.8)** as indicating the process to be the endothermic.

CONCLUSION

The present study shows the potential of soil as sorbent for benzene wastewater treatment .This treatment is simple and economic. Such a batch system will be applicable to small industries generating benzene containing wastewaters. The sorption kinetics data thus generated may be used for designing a treatment plant for benzene effluents wherein continuous removal or collection can be achieved on a large scale. Soil can effectively remove benzene from aqueous solutions through adsorption processes, with removal efficiency influenced by various factors including soil properties, pH, temperature, and the presence of competing contaminants. Understanding these removal characteristics is crucial for designing effective remediation strategies for benzene-contaminated sites.

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Table – 1 Proximate Analysis of Fraction of 75μm soil Samples.

Element as oxide	Weight%
SiO_2	74.47
Al_2O_3	8.97
Fe_2O_3	10.84
SO3	2.85
CaO	0.37
MgO	0.69
TiO2	1.09
LOI(800^{0}C)	4.3
Specific gravity	2.47
Moisture Contents(%)	4.60
Volatile Matter (%)	7.01
Fixed Carbon (%)	4.7
Surface Area	20.040s/g
Pore Volume	4.489e$^-$

Table – 2 X-ray fluorescence (XRF) analyses for the soil sample

Element as oxide	Weight%
SiO_2	74.47
Al_2O_3	8.97
Fe_2O_3	10.84
SO3	2.85
CaO	0.37
MgO	0.69
K_2O	0.60
MnO	0.15
TiO2	1.09

Table 3: pseudo- first- order (Lagergren) rate constant of Adsorbate on soil

Adsorbate	**Condition**	**Rate constant (min^{-1})**	
		k(min1)x10^{-2}	**R^2**
Benzene	Particle Size 75(μm)	3.68	0.991
Nitrobenzene	pH6.5	2.99	0.977
Bromobenzene	Concentration 500(mg/L) Temperature 30C^0.	4.14	0.974
Clorobenzene		4.37	0.965

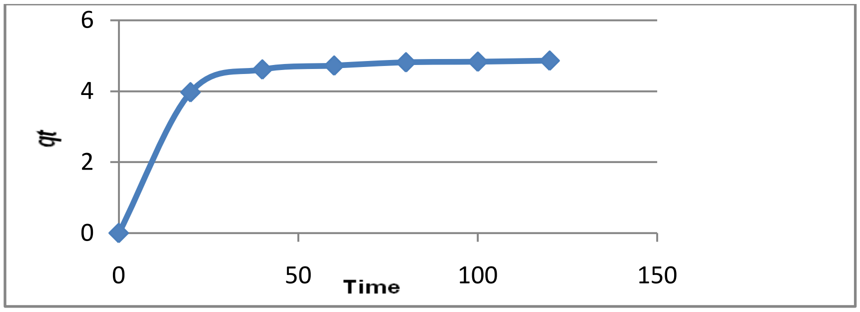

Fig. 1.1 Adsorption Kinetics of Benzene on soil; condition: 500 mgl $^{-1}$; pH 6.5; Temperature 30°c

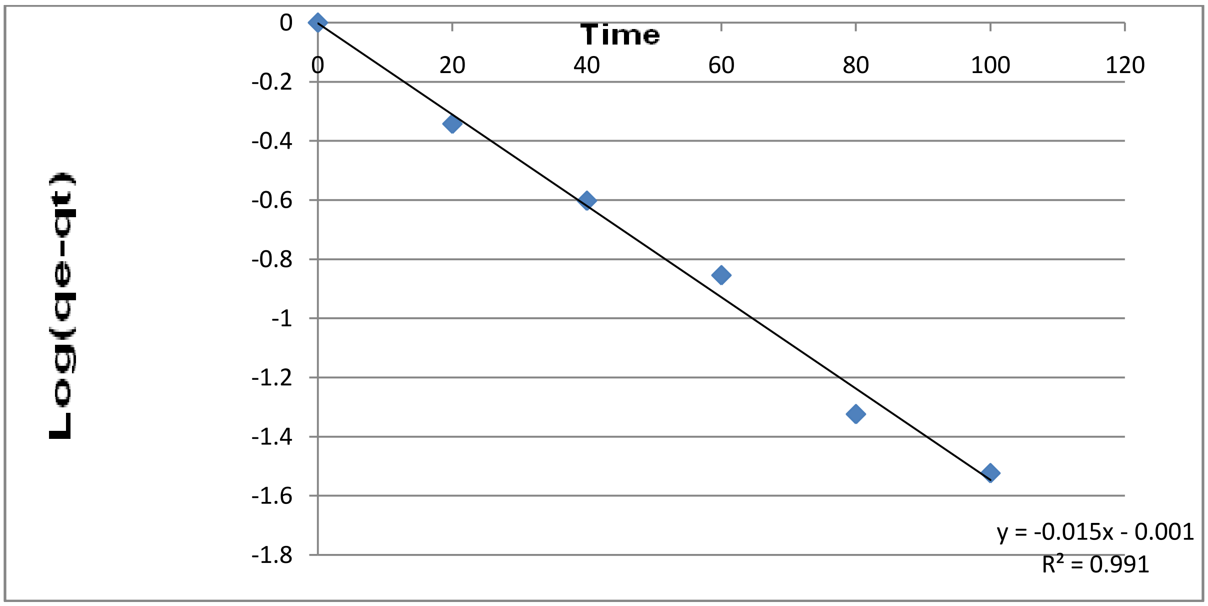

Fig. 1.2 Lagergren plot for the adsorption of Benzene on Soil;Concentration 500 mgl $^{-1}$; Size 150µm ; Temerature 30°C

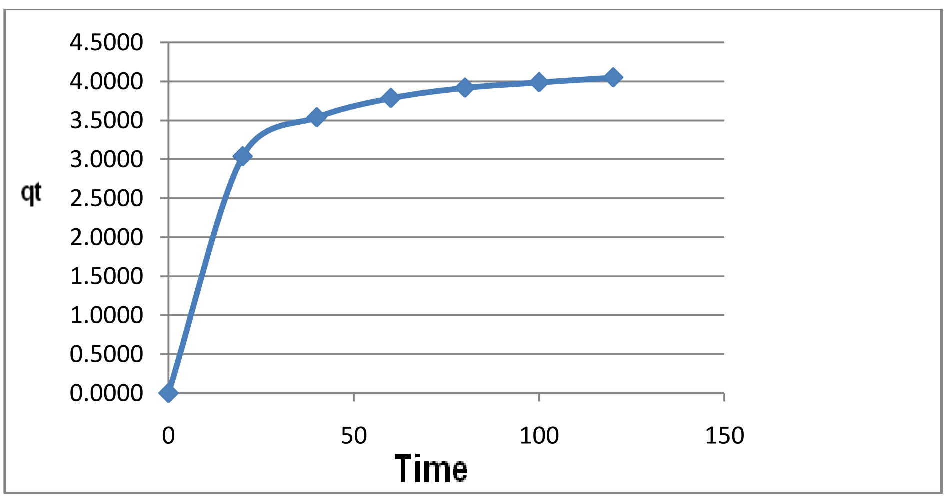

Fig. 1.3 Adsorption Kinetics of NitroBenzene on soil; condition: 500 mgl $^{-1}$; pH 6.5; Temperature 30°c

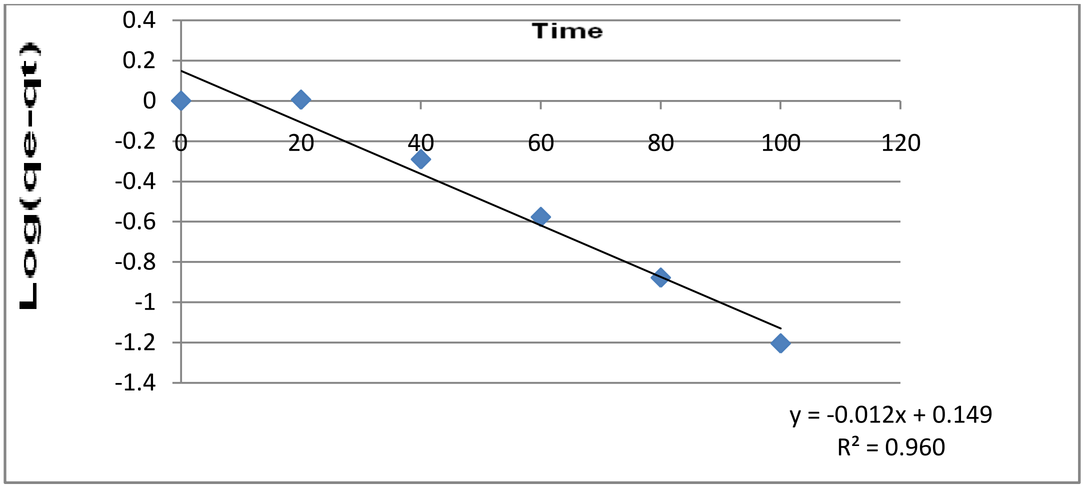

Fig. 1.4 Lagergren plot for the adsorption of Nitrobenzene **on Soil; Concentration 500 mgl^{-1}; Size 150µm ; Temerature 30°C**

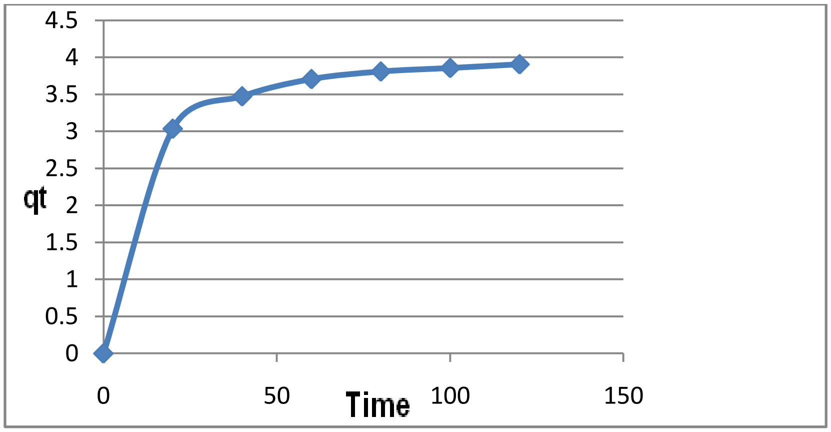

Fig. 1.5 Adsorption Kinetics of Clorobenzene on soil; condition: 500 mgl $^{-1}$; pH 6.5; Temperature 30°c

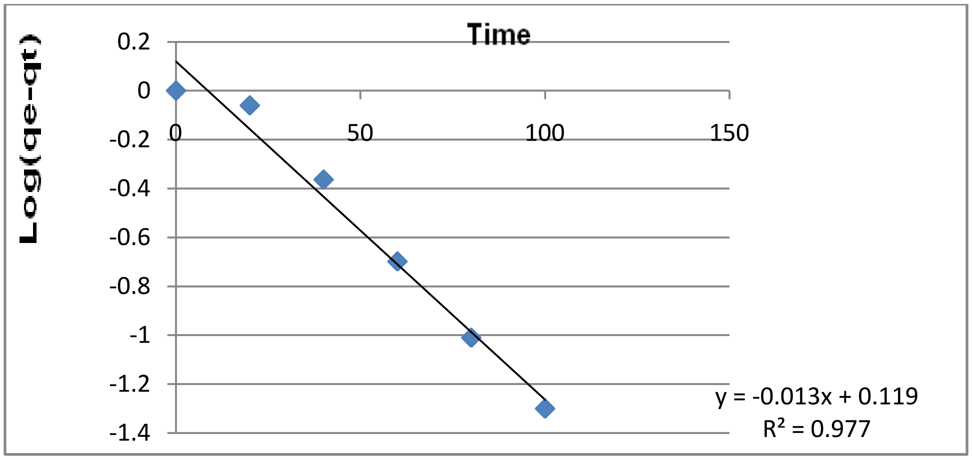

Fig. 1.6 Lagergren plot for the adsorption of Clorobenzene **on Soil;Concentration 500 mgl^{-1}; Size 150µm ; Temerature 30°C**

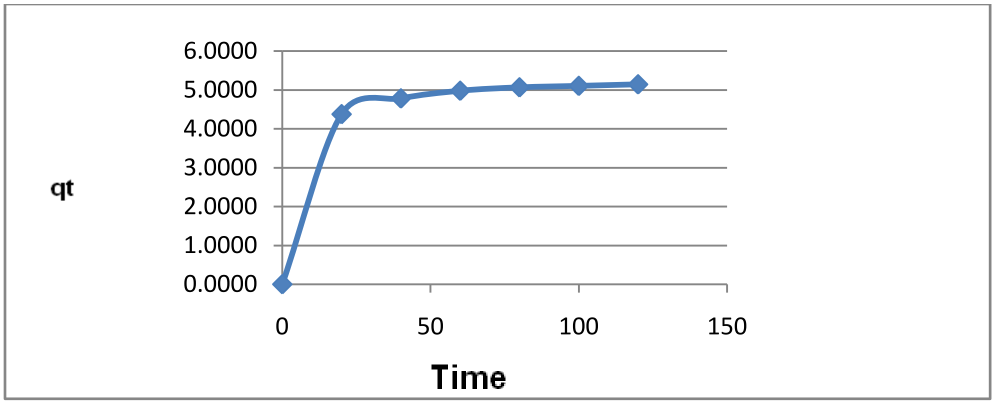

Fig. 1.7 Adsorption Kinetics of Bromobenzene on soil; condition: 500 mgl $^{-1}$; pH 6.5; Temperature 30°c

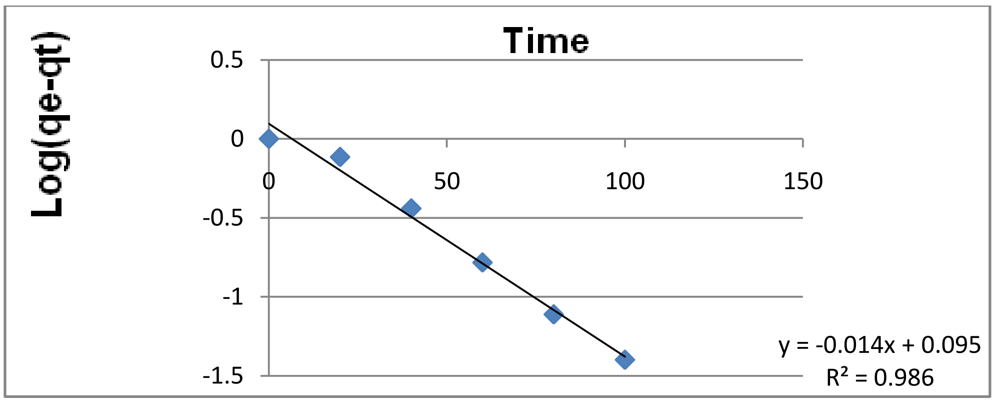

Fig 1.8 Lagergren plot for the adsorption of Bromobenzene on soil; Concentration 500 mgl^{-1}; pH 6.5; Temerature 30°c .