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Dynamics of adsorption isotherms for the treatment of domestic effluents with novel isolated microorganism

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ABSTRACT

Microorganisms possess a capacity to accumulate organic and inorganic matter in their body, evoke the process of their enzymatic transformation and adsorb them on the cell surface. Detailed batch studies with the selected JH4 microbial biomass as a adsorbent, has been carried out to investigate the effect of pH, contact time on the adsorption isotherm for TS, TDS and Hardness. Isolated bacterial strains JH4 posses the capacity to reduce TS, TDS and Hardness of water about 82±2 % at pH 7 with contact time of 85 minutes. The adsorption kinetic study satisfied the model Langergren and Frendulich equilibrium constant. Adsorption capacity was found to be 47.2, 27 and 26 mg/g of of adsorbent for TS, TDS and hardness respectively.

KEYWORDS

Adsorption;
Total solid;
Dissolved solid;
Bioremidation;
Lagregren kinetic;
Freundlich isotherm.

INTRODUCTION

Water reserves of the world are limited. and only a little amount of freshwater is accessible to humans. Bioremediation, a biological process using microorganisms as agents for remedial activities have been developed to degrade, detoxify or accumulate contaminating chemicals. Microorganisms are capable of degrading a variety of pollutants. Biological processes play a major role in the removal of contaminants and they take advantage of the astonishing catabolic versatility of microorganisms to degrade/convert such compounds. Interest in the microbial biodegradation of pollutants has intensified in recent years as mankind strives to find sustainable ways to cleanup contaminated environments. These bioremediation and biotransformation methods endeavor to harness the astonishing, naturally occurring, microbial catabolic diversity to degrade, transform or accumulate a huge range of compounds. The purpose of treatment is to remove the contaminants from water so that the treated water can meet the acceptable quality standards. Domestic effluent is emerging out from houses, towns and municipalities and contains excessive amounts of Total solid (TS), Total dossilved solid (TDS) These solids reduce water clarity, contribute to a decrease in photosynthesis, combine with toxic compounds and heavy metals, and lead to an increase in water temperature[5]. Hardness is due to the presence of calcium, magnesium or ferrous (iron salts) as chloride, sulphate or bicarbonates. Hardness affects the amount of soap that is needed to produce foam or lather. Hard water requires more soap, because the calcium and magnesium ions form complexes with soap, preventing the soap from sudsing. Hard water can also

TABLE 1: Treatment of effluent with isolated microorganisms

Parameter	Effluents	% removal of various parameter with isolated microorganism											
		JH1	JH_2	JH_3	JH_4	JH_5	JH_6	JH_7	JH_8	JH_9	JH_{10}	JH_{11}	JH_{12}
pH	5.4	-	-	-	-	-	-	-	-	-	-	-	-
TS	11800 ppm	57.8	42	28.1	68.2	65.3	48.1	54.2	35.7	58.0	40.2	62.5	36.7
TDS	5600 ppm	46.8	57.6	51.0	70.6	54.3	61.8	28.7	41.3	64.5	51.0	56.8	59.8
Hardness	650 ppm	63.1	37.6	65.2	68.9	43.6	58.9	50	41.4	56.5	30.2	28.3	49.4
Alkalinity	480 ppm	45.5	51.7	34.2	67.7	62.8	49	42.1	60.1	48.1	63.2	50.0	62.8
Conductivity	3.9 mS/cm	57.3	51.4	42.8	69.3	44.6	67.7	30.8	42	39.6	25.5	40.7	45.9
Turbidity	11 NTU	47.6	63.5	38.9	71.2	38	52.8	45.7	50.3	36.1	32.0	65.4	61.0
BOD	220 ppm	-	-	-	-	-	-	-	-	-	-	-	-
COD	450 ppm	-	-	-	-	-	-	-	-	-	-	-	-

leave a film on hair, fabrics, and glassware. Hardness of the water is very important in industrial uses, because it forms scale in heat exchange equipment, boilers, and pipelines. Some hardness is needed in plumbing systems to prevent corrosion of pipes Aspect of the present study is aimed at selection of a microbial biosorbent, which can adsorb pollutant from the wastewater. Detailed batch studies with the selected microbial biomass as a adsorbent, has been carried out to investigate the effect of pH, contact time on the Langmuir and Freundlich adsorption isotherm for TS, TDS and Hardness.

MATERIALS AND METHOD

General characterization of domestic effluent

Domestic effluent was collected and parameters i.e. total solids, total dissolved solids, alkalinity, hardness, conductivity, turbidity, DO, BOD and COD was determined by standard methods[6] with slight modification.

Isolation and screening of microorganisms for the domestic effluents treatment

Isolation of microorganisms was carried with the help of streak plate methods from domestic effluent and different colonies were identified based on color, size and shape. Isolated microorganism was inoculated in sterilized liquid medium (gm/l) ;Yeast Extract, 2 ; Beef Extract,1; Peptone,5; Sodium Chloride,5 and after incubation (24 hours at 37^0C for) broth was centrifuged (5000 rpm at 4^0C and 20 minutes) for microbial biomass separation. To study the adsorption potential 1 gm microbial biomass was added in the 100 ml of domestic effluent and placed on the rotary shaker at 30 ± 2^0C and after 24 hrs filtrate was analsed for the for the parameters i.e. total solids, total dissolved solids and Hardness.

Effect of pH and contact time on the adsorption potential of microorganism for the treatment of domestic effluent

All the batch adsorption studies was carried at pH 2, 4, 7 and 9 using 100 ml of domestic effluent in 250 ml Erlenmeyer conical flask. Requisite quantity of microbial biomass was added and placed on rotatory shaker at 30 ± 2^0C. Samples were withdrawn after different time intervals for the analysis of residual TS, TDS and hardness.

RESULTS AND DISCUSSION

Different parameters of domestic effluent i.e. pH, total solids, total dissolved solids, alkalinity, hardness conductivity, turbidity, DO, BOD and COD were determined by standards procedure and from the results is was concluded that all the parameters are above the mentions limits by the IDAPA[3] and EPA[8] standard. For the treatment of effluent isolated microorganism, JH4 has higher the adsorption potential for the various parameters with respect to the other (TABLE 1) because microorganisms exposed continuously to an environment for a prolonged period of time, acquire new genetic properties to live in alien environment by mutation, substitution and expression of new genes[4].

Effect of pH and contact time for the removal of TS and TDS with microbial biomass

Effect of pH

Effect of solution pH on removal of total solids an

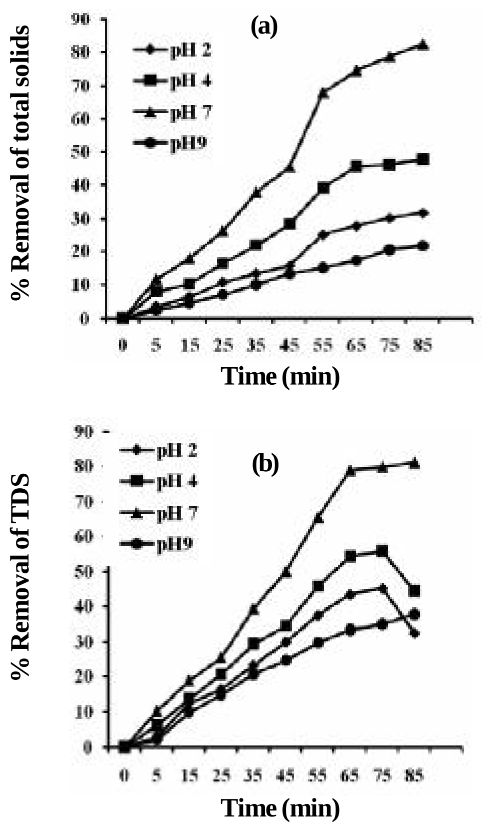

Figure 1: Effect of pH and contact time on removal of TS (a) and TDS (b) by microbial biomass with pH 2, 4, 7, 9 at 30±2^{0}C. Adsorbent dose 10gm/L

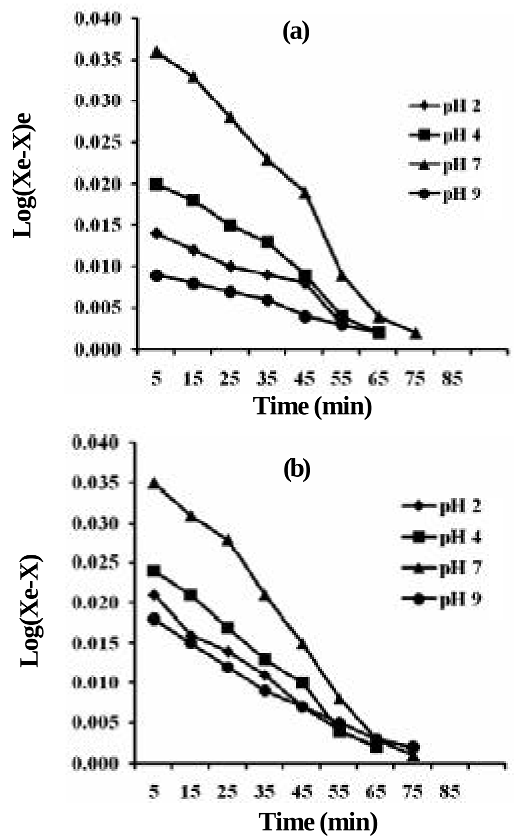

Figure 2 : Langergren plot for the adsorption of (a)TS (b) TDS by microbial biomass with pH 2, 4, 7, 9 at 30±2^{0}C. Adsorbent dose 10gm/L

dissolved was studied using biomass as an adsorbent. As pH of solution was increased from 2 to 7 the adsorption increased from 31-82 and 45-81% for TS and TDS respectively. When pH was increased from 7-9 the % of TS and TDS removal decreased significantly 21 and 38 % respectively. Maximum removal of TS and TDS was achieved at pH 7. Thesr values ate comparable to for the removal of suspended solids from the sewage[2].

Effect of contact time

Figure 1 (a, b) shows the effect of contact time for the removal of TS and TDS. Increasing contact time from 5-85 minute increases the percentage removal of TS and TDS. Maximum removal was within 45-85 min. contact time. The kinetic data was fitted to the Lagergren equation[7].

$\log (X_e - X) = \log X_e - K_{ads}\, t/2.303$

X= the amount of solute, total solids (mg/g of adsorbent) removed at time t, X_e = amount removed at equilibrium and K_{ads} = the rate constant of adsorption. The effect of contact time was studied for the removal of TS and TDS with different pH 2, 4, 7 and 9 at 30±2^{0}C. For biomass, the contact time of more than 1 hour was needed to establish equilibrium. The kinetic of effluent at different pH with biomass as an adsorbent was found to be first order rate. Figure 2(a, b) depict Lagergren plot with regressions coefficient 0.9 for TS and TDS. Adsorption rate constant are given in TABLE 3.

Adsorption isotherms

Adsorption isotherms, which are the presentation of the amount of solute adsorbed per unit of adsorbent, as a function of equilibrium concentration in bulk solution at constant temperature, were studied. Several models have been developed to describe adsorption system behaviors. The Langmuir isotherm model has been successfully applied to many pollutant adsorption processes and it is most commonly used adsorption

TABLE 2 : Effect of pH on the adsorption 6rate (K_{ads} (min^{-1}) and Thermodynamic equilibrium constant (K^0_c) for the TS and TDS

pH	Adsorption rate constants K_{ads} (min^{-1}) for		Thermodynamic equilibrium constant (K^0_c)	
	TS	TDS	TS	TDS
2.0	3.1×10^{-2}	3.5×10^{-2}	0.46	0.37
3.0	3.7×10^{-2}	3.9×10^{-2}	0.91	1.26
7.0	4.9×10^{-2}	4.9×10^{-2}	4.72	4.32
9.0	2.4×10^{-2}	2.9×10^{-2}	0.27	0.61

TABLE 3 : Adsorption rate constants for biomass at different pH

S. no.	pH	Adsorption rate constant K_{ads}(min^{-1})	Thermodynamic equilibrium constant ($K°_c$)
1	2.0	2.8×10^{-2}	0.55
2	3.0	3.1×10^{-2}	1.08
3	7.0	4.8×10^{-2}	4.16
4	9.0	3.2×10^{-2}	0.79

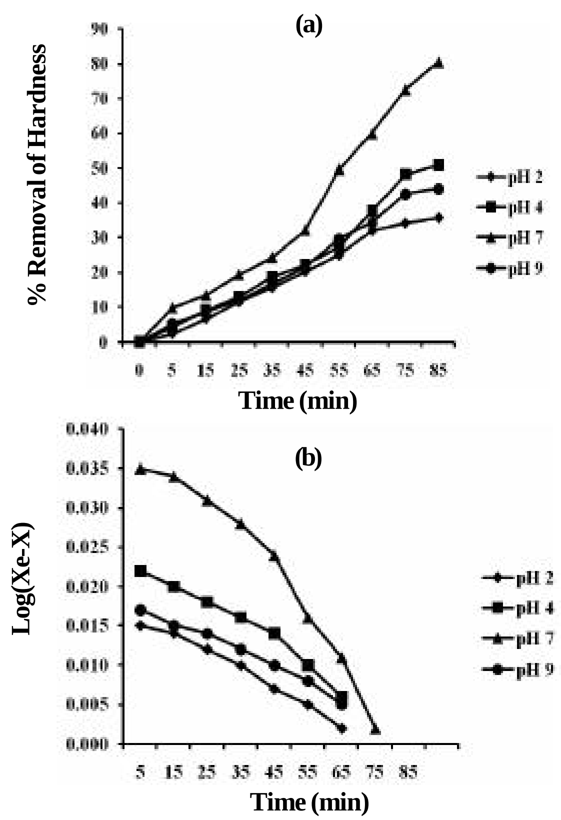

Figure 3 : (a) Effect of pH and contact time on removal of hardness by microbial biomass with pH 2, 4, 7, 9 at 30±2^{0}C. Adsorbent dose 10gm/L; (b) Langergren plot for the adsorption of Total solids by microbial biomass with pH 2, 4, 7, 9 at 30±2^{0}C. Adsorbent dose 10gm/L

isotherm for the adsorption of a solute from a liquid solution (Langmuir, 1916). The linear form of Langmuir isotherm is given by the following equation:

$$C_e/q_e = 1/(q_m Ka) + C_e/q_m$$

Where q_e is the amount adsorbed per unit mass of adsorbent (mg/g), C_e the equilibrium concentration of the adsorbate (mg/l), q_m the equilibrium sorption capacity for complete monolayer (mg/g) and Ka the sorption equilibrium constant (l/mg).

The Freundlich isotherm[1] is the earliest known relationship describing the sorption equation. This fairly satisfactory empirical isotherm can be used for non-ideal sorption that involves heterogeneous sorption. The linear form of Freundlich isotherm is given by the following equation:

$$\text{Log}(q_e) = 1/n \log(C_e) + \log(KF)$$

Thermodynamic equilibrium constant for effluent using microbial biomass as adsorbent was obtained at 32^{0}C,

$$K^0C = C_a / C_e$$

Here C_a was concentration on adsorbent at equilibrium in mg/l and C_e is the equilibrium concentration of solids in solution in mg/l. Results (TABLE 2) depicts the thermodynamic equilibrium constants for TS and TDS.

Effect of pH and contact time on the adsorption potential of microorganism for the treatment of hardness

Hardness is measure of polyvalent cations in water. Hardness generally represents the concentration of calcium (Ca^{2+}) and magnesium (Mg^{2+}) ions, because these are the most common polyvalent cations. Other ions, such as iron (Fe^{2+}) and manganese (Mn^{2+}), may also contribute to the hardness of water, but are generally present in much lower concentrations. Waters with high hardness values are referred to as "hard," while those with low hardness values are "soft".

Effect of solution pH on removal of hardness was studied using biomass as a adsorbent. As pH of solution was increased from 2-7 percentage removal increased from 35-80 %, whereas when the pH was increased from 7-9 percentage removal decreased significantly from 80-44.17%. (Figure 3a). Increasing contact time (5-85 min.) increases the removal of hardness with Maximum removal was observed within 45-85 min. For biomass, the contact time of more than 1 hour was needed to establish equilibrium. The kinetic of effluent at different pH with biomass as an adsorbent was found to be first order rate. Figure 3b) depict Lagergren plot with regressions coefficient 0.9 for hardness. As the pH of solution was increased from pH 2-7 the adsorption rate constants increased. Adsorption rate constant (TABLE 3) value was observed maximum 4.8×10^{-2} at pH 7 while as the pH increased from 7-9 the Adsorption rate constant decreased

CONCLUSION

Removal of TS, TDS and hardness was possible by using microbial based biosrbent. Isolated microorganism JH4 was most effective for removal of TS, TDS and hardness up to 82±2 percentage at pH 7. Contact time of 85 minutes was optimum to achieve the equilibrium. Kinetics of adsorption was found to the follow the first order mechanism. Adsorption rate constant was 4.9×10^{-2} for TS and TDS. Thermodynamic Equilibrium Constant (K^0c) was 4.72 and 4.32 for TS and TDS at pH 7. For the removal of hardness from the water microbial biomass has first order rate mechanism. So form the result it is concluded that biomass can be used for the effluent treatment

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