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Chitosan as an Adsorbent for Removal of Total Dissolved Solids and Hardness with Equilibrium Analysis

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ABSTRACT

This study investigates the potential of Chitosan, a biopolymer derived from chitin, as an adsorbent for the removal of Total Dissolved Solids (TDS) and hardness from water samples. The research explores the impact of key adsorbent parameters, including contact time and adsorbent dosage, on the efficiency of TDS and hardness removal. Experiments were conducted using water samples from four different locations. The effect of contact time was studied by exposing the water samples to Chitosan for varying durations, while different doses of Chitosan were tested to determine optimal conditions for maximum removal efficiency. The adsorption process was analyzed using isotherm models to understand the adsorption behavior and predict equilibrium conditions. The Langmuir and Freundlich isotherm models were applied to fit the experimental data and assess the adsorption capacity of Chitosan. Results indicate that Chitosan exhibits promising adsorption capabilities for both TDS and hardness removal. The efficiency of adsorption is influenced significantly by contact time and adsorbent dosage, with optimal conditions identified for maximum removal efficiency. The adsorption isotherm analysis revealed that the adsorption of TDS and hardness ions onto Chitosan follows a monolayer adsorption mechanism, as indicated by the Langmuir model. This research contributes to the understanding of Chitosan as a potential eco-friendly adsorbent for water treatment applications, offering insights into optimal operational parameters for enhanced TDS and hardness removal. The findings underscore the importance of considering adsorbent characteristics and process conditions in designing effective water treatment strategies.

Keywords: Chitosan, Adsorbent, Isotherm, Total Dissolved Solids, Hardness

INTRODUCTION

The Total Dissolved solids is a crucial indicator for chemical water quality, indicating the presence of inorganic and organic salts. Materials in a water solution. Water hardness specifically refers to the concentration of dissolved minerals, primarily calcium and magnesium ions, in water. There are two main types of water hardness: temporary and permanent. Temporary hardness is caused by the presence of dissolved bicarbonates (carbonates and bicarbonates) of calcium and magnesium. It can be removed by boiling the water. Permanent hardness, on the other hand, is caused by the presence of dissolved sulphates, chlorides, and nitrates of calcium and magnesium. It cannot be removed by boiling. Water hardness is typically measured in terms of calcium carbonate equivalents (mg/l $CaCO_3$). The Environmental Protection Agency (EPA) in the United States has set a maximum contaminant level (MCL) for TDS in drinking water at 500 milligrams per liter (mg/l). The World Health Organization (WHO) also provides guidelines for TDS in drinking water, with a recommended limit of 1000 parts per million (ppm). These regulatory limits are designed to protect public health by ensuring that drinking water is free from harmful levels of dissolved contaminants and mineral

STUDY AREA

In this study, four groundwater samples are collected from different locations in Pune city are follows: **S1**-GSMCOE Balewadi
S2 -Bhosari
S3- Sus village
S4- Pimpri Telco

Fig no. 1 Location of GSMCOE Balewadi (S1)

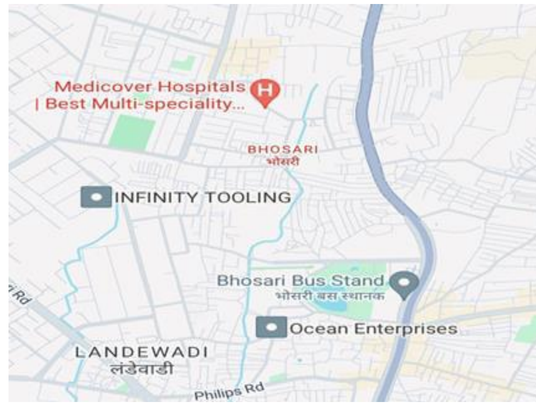


Fig no. 2 Location of Bhosari (S2)

Fig no. 3 Location of Sus village (S3)

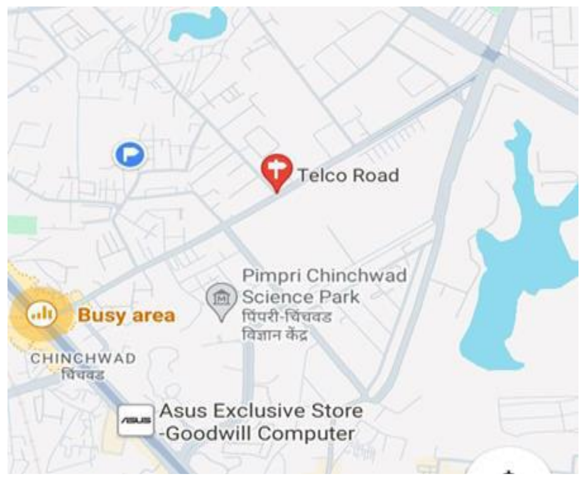


Fig no. 4 Location of Pimpri Telco (S4)

MATERIAL AND METHODOLOGY

Preparations of adsorbent

For this study, Chitosan is selected as the adsorbent material. Raw Chitosan flakes available from Jharkhand were collected and cleaned to remove dirt and dust particles, chitosan flakes were scattered into 75 ml of distilled water and were and stirred at 160 rpm using magnetic stirrer.

Fig no. 5 Chitosan Flakes

Table no. 1 chitosan specification

TEST	PARAMETERS	UNITS	STD. RANGE	VALUE
general properties	Product name Cas. no. Origin			CHITOSAN 9012-76-4 Shrimp Chitin
physical properties	Physical form Solubility in water Solutions appearance Smell Colour Viscosity	% CP	Insoluble clear odourless off white >100	Pulverized Confirms Confirms odourless white 120
chemical properties	Degree of deacetylation Ash content Moisture content Protein content Acid insoluble matter Heavy matter analysis Lead Arsenic Mercury Cadmium	% % % % % ppm ppm ppm ppm ppm	85-90 <1.0 <10 nil <1.0 <5.0 <0.5 <0.5 <0.1 <1.0	96% <1.0 <10 non dectable <1.0 conforms conforms conforms conforms conforms

Batch experiments:

The levels of total dissolved solids are measured using a TDS meter available in the laboratory of the Genba Sopanrao Moze college of engineering balewadi and hardness measured by using the titration method. Initially, 100 ml of groundwater samples from each selected location have been taken in 500 ml and 1000 ml capacity glass containers. Different doses of adsorbents (chitosan) i.e., 0.5, 1, 1.5, 2, 2.5, and 5 mg/100 ml of groundwater samples are used. The glass container containing the mixture has been agitated by using an electrostatic magnetic stirrer at the speed of 20 rpm for 10 min duration at room temperature. After complete mixing of the adsorbent material, the suspension has been allowed to stand without any disturbance for settling for up to 30 min. The supernatant is filtered by using Whatman filter paper. In the end, the level of total dissolved solids, hardness filtrate samples are determined.

Table no. 2 -Ground water sample TDS level & hardness

Sr. No	Location	TDS level	Hardness
1	**GSMCOE Balewadi**	**234.5 mg/L**	**210 mg/L**
2	**Bhosari**	**187.1 mg/L**	**465 mg/L**
3	**Sus Village**	**612 mg/L**	**367.2 mg/L**
4	**Pimpri Telco**	**223mg/L**	**555 mg/L**

Percentage Removal

The percentage of removal efficiency formula is frequently used to calculate the performance of chitosan and evaluate the number of contaminants that were removed. The percentage of removal was represented below:

$$\text{Percentage Removal (\%)} = \frac{Ci - Cf}{Ci} 12 \times 100$$

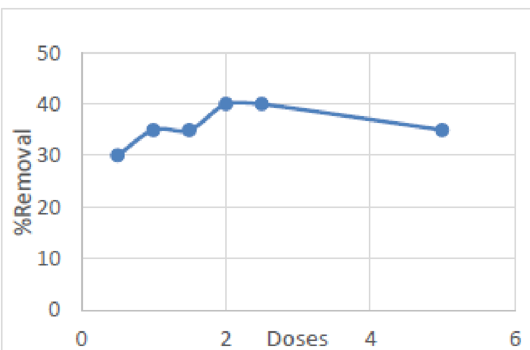
where, Ci and Cf represent the initial and equilibrium concentrations of all parameters in kitchen wastewater in mg/L, respectively.

RESULTS AND DISCUSSIONS

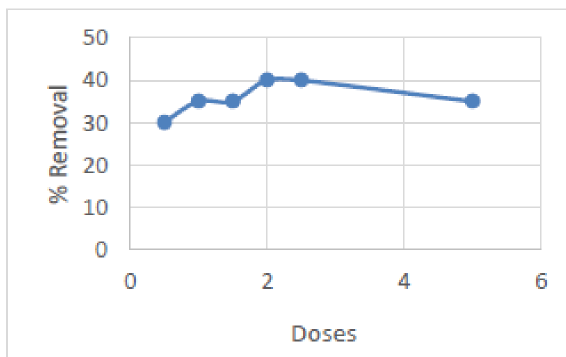
The effect of doses on sample S1, S2, S3, and S4 are seen as follow

Table no. 3 Effect of doses

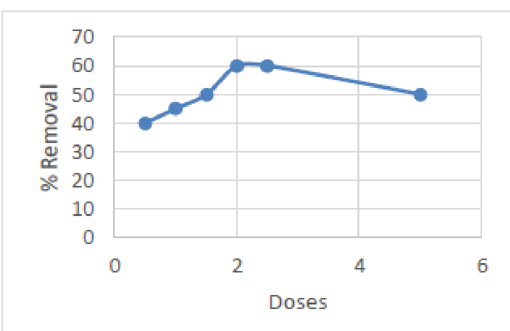
Doses in gm	Removal % (S1)	Removal % (S2)	Removal % (S3)	Removal % (S4)
0.5	10	30	40	35
1	20	35	45	40
1.5	25	35	50	45
2	30	40	60	50
2.5	30	40	60	50
5	25	35	50	45



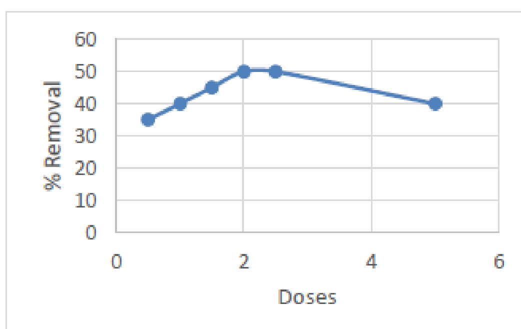
Graph no. 1 Effect of doses on S1



Graph no. 2 Effect of doses on S2



Graph no. 3 Effect of doses on S3

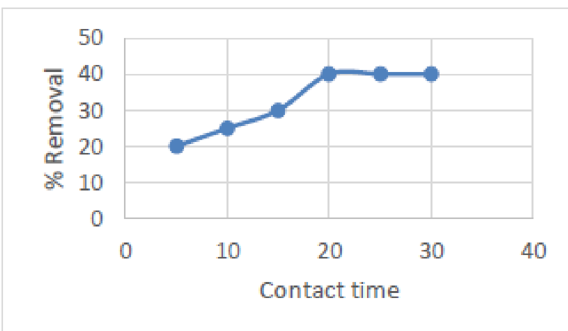


Graph no. 4 Effect of doses on S4

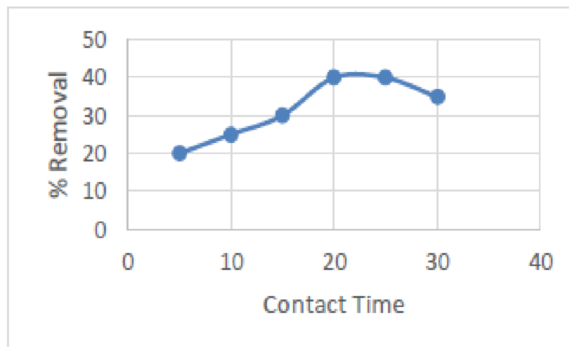
The effect of contact time on sample S1, S2, S3, and S4 are seen as follow;

Table no. 4 Effect of contact time

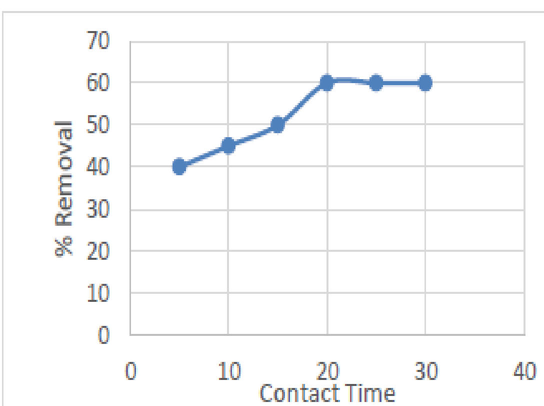
Doses in gm	Removal % (S1)	Removal % (S2)	Removal % (S3)	Removal % (S4)
0.5	10	30	40	35
1	20	35	45	40
1.5	25	35	50	45
2	30	40	60	50
2.5	30	40	60	50
5	25	35	50	45



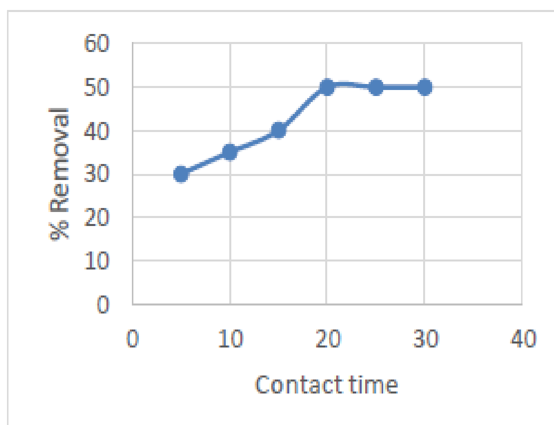
Graph no.5 Effect of contact time on S1



Graph no.6 Effect of contact time on S2



Graph no.7 Effect of contact time on S3



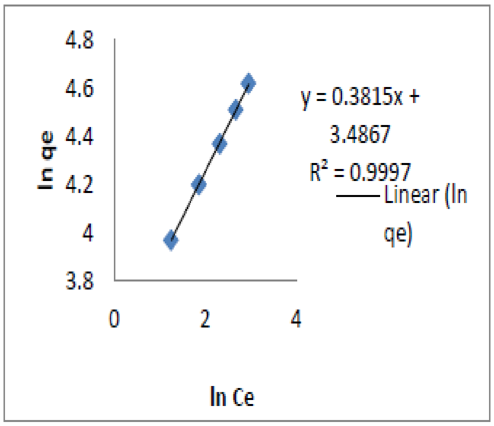
Graph no.8 Effect of contact time on S4

It observed that in groundwater samples reduces the number of dissolved salts and solids (TDS). Higher doses of Chitosan are more effective at cleaning the water. Groundwater samples with higher salt concentrations have more salts removed compared to samples with lower salt levels. This means the chitosan works better when there are more salts to remove. Chitosan is good at reducing water hardness. When using 2grams of chitosan for 20 minutes, it reduced hardness by 30% in S-1, 40% in S-2, 60% in S-3, and 50% in S-4.

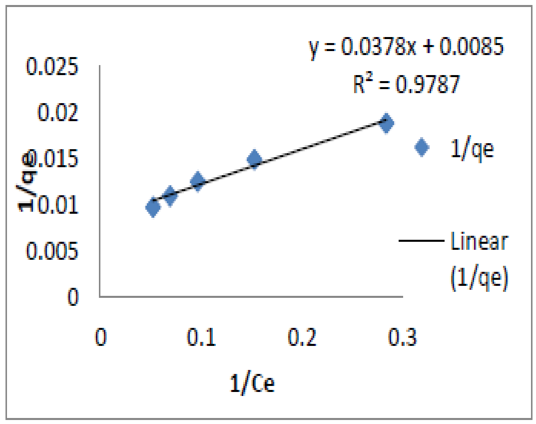
The results obtained after using various adsorbent doses for the reduction from groundwater samples are given in Fig. 4. Moreover, the minimum reduction of hardness and TDS level is noted in the sample S-1 with a 10% reduction at a 0.5-g dose, and maximum reduction is noted by using a 2.-gms dose of adsorbent with a 30% reduction at the retention time 20 min In sample S-2, a reduction has been noted with 30% at a 0.5-g dose of adsorbent, while, the maximum reduction is observed with a 40% reduction by using a 2-g dose of adsorbent at the retention time of 20 min. Similarly, in S-3, the minimum reduction is observed at the adsorbent dose of 0.5 g, and the maximum reduction has been found by using a 2.-g dose of adsorbent with 60% reduction at the retention time of 20 min. Moreover, the minimum reduction is noted in the sample S-4 at the adsorbent dose of 0.5 g of adsorbent dose with 35%, whereas the maximum reduction is observed by using 2 g of adsorbent dose with a reduction of 50% at the retention time of 20 min.

ISOTHERM STUDIES

Adsorption isotherms are important for explaining how adsorbent concentration interrelates with adsorbate media and are helpful to optimize the utilization of media as adsorbent. This isotherm quantitatively describes the formation of monolayer adsorbate on the outer surface of adsorbent, and after the process no adsorption takes on further. Therefore, this isotherm shows the Equilibrium distribution of metal ions between the solid and liquid phases.



Graph no.9 Freundlich isotherm



Graph no.10 Langmuir isotherm

FITTED ISOTHERM PARAMETERS

Table no .5 Evaluation of Freundlich and Langmuir isotherm to find out adsorption behavior of Chitosan-for adsorption

FREUNDLICH ISOTHERM	LANGMUIR ISOTHERM
K=32.65MG/G	Q0=125MG/G
N=2.62	KL=0.216
R2=0.999	R2=0.978

Freundlich and Langmuir isotherm plot of adsorption by Chitosan-demonstrated graph no.9 and graph no.10.The coefficient of regression R2 is observed to be.0.999 and 0.978 for Freundlich and Langmuir isotherms, respectively. From the regression coefficients, it can be said that the Freundlich isotherm is the best fit out of two

CONCLUSIONS

Based on the study's findings, the effectiveness of Chitosan as an adsorbent in reducing total dissolved solids (TDS) and hardness in groundwater at various locations in Pune was evaluated. Thorough mixing of the adsorbent with the samples before the 20minute retention interval was recommended for optimal results. The investigation demonstrated that utilizing 2 grams of Chitosan as an adsorbent resulted in significant removal efficiencies for total dissolved solids and hardness reduces 30%,40%,60%, and 50 % respectively. This indicates the potential of Chitosan as a viable option for groundwater treatment.

Furthermore, the analysis of adsorption isotherms revealed that the Langmuir isotherm provided a better fit to the equilibrium data compared to the Freundlich isotherm, with respective R^2 values of 0.999 and 0.978. This suggests that the adsorption of contaminants onto Chitosan likely occurred in a monolayer fashion.

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