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Arsenic Adsorption from Aqueous Solution Using Chitosan Nanoparticle

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ABSTRACT

Arsenic is a major pollutant for the environment, therefore using Chitosan nanoparticle the adsorption study was performed for adsorbing the Arsenic. Chitosan nanoparticle was prepared by ionic gelation method by using chitosan and Sodium tripolyphosphate (CS-STPP). The morphology and structure of chitosan nanoparticles was characterized Scanning Electron Microscope (SEM), Fourier transform infrared spectroscopy (FT-IR) spectra and X-ray diffraction (XRD) showed the chitosan converted into chitosan nanoparticle. The adsorption capacity and adsorption isotherms using Langmuir and Freundlich isotherm for arsenic ions were investigated by equilibrium studies. Factors such as concentration of Chitosan nanoparticle, temperature effect on adsorption of arsenic and effect of pH and adsorption capacity was investigated. It is found that chitosan nanoparticles could adsorb arsenic (arsenic trioxide) effectively, the maximum capacity of arsenic (arsenic trioxide) adsorbed was obtained in Langmuir isotherm equation which showed it followed monolayer adsorption of Langmuir isotherm experimental data of arsenic adsorption equilibrium correlated well with the Langmuir isotherm equation, thus showing that chitosan nanoparticle is a good adsorbent for adsorption of water from aqueous solution.

Key words: Chitosan nanoparticle, arsenic, adsorption equilibrium, adsorption isotherms

INTRODUCTION

Arsenic is heavy metal contaminant found distributed heavily in the environment as contaminants, Arsenic is present in water by natural and anthropogenic activities. Organic arsenic can occur in the environment in several forms. In natural waters and thus in drinking water, it is mostly found in trivalent form arsenic (III) (e.g., Arsenic trioxide) or pentavalent form (e.g., Arsenic pentaoxide). Arsenic widely used in industries and is released through industrial waste water, this arsenic is used in microelectronics devices and is also used as pesticide and wood preservative. Mining activities also generate large amounts of contaminated wastewater since arsenic is present as a mixture in molybdenum, lead and copper ores. The wastewater generated during the hydrometallurgical treatment of these minerals usually contains high arsenic levels. Usual treatments for arsenic removal consist of flotation, co-precipitation with ferric chloride, sulfide precipitation or lime softening, involving the production of highly toxic sludge, which must be further treated before being environmentally safe for disposal (Bhattacharyya *et al.*, 1979). Among all the above processes adsorption has been recognized as an effective technique for treatment of

water contaminated with arsenic. Sorption processes are found to be capable of adsorbing large number of metal ions from contaminated waste water; some of the sorbents used for adsorbing metal ions are activated carbon, minerals, fly ash, industrial wastes, coral limestone or biological materials such as living or non-living biomass. One of the best approaches of performing adsorption process is by a biopolymer chitosan (Ohki *et al.*, 1996). Chitosan is an alkaline deacetylated product of chitin, was used extensively due to its high hydrophilicity, presence of a large number of hydroxyl and amino groups with high activity as adsorption sites, nontoxicity, abundance in nature, biocompatibility and biodegradability. Chitosan has been found as found as a best approach for metal recovery which is found to be more efficient for the removal of metals such as uranium, copper, vanadium and molybdenum, with high uptake capacities (Guibal *et al.*, 1994). In many studies such as adsorption of metals (Copper, Zinc), polymer supported nanoparticles has been prepared and used for selective removal of metal compounds and target metal contaminants (Xu and Du, 2003). Chitosan nanoparticles had been synthesized based on polymer natural source (Crab, shellfish) and applied as drug carriers (Pan *et al.*, 2002).

The first objective was to develop a novel adsorbent to remove As(III) from water, using the biosorbent chitosan nanoparticle. The second objective was to evaluate adsorption capacity of the adsorbent for As(III) under equilibrium and dynamic experimental conditions. The third objective was to study the functional groups of the biopolymer chitosan nanoparticle responsible for adsorbing Arsenic trioxide (As (III)) using FTIR. The equilibrium adsorption data was fitted to Langmuir isotherms and Freundlich isotherm.

MATERIALS AND METHODS

Materials: Chitin was obtained from Chitin Company of Taiwan; the obtained chitin was deacetylated by adding sodium hydroxide (purchased from Lobachemie. Pvt. Ltd.) and chitosan was obtained after 24 h, it was then washed with double distilled water and then finally dried and stored at room temperature. Sodium Tripolyphosphate (STPP), Sodium alginate, Sodium chloride (NaCl), calcium chloride (CaCl_2) was purchased from Lobachemie. Pvt. Ltd and Arsenic trioxide was purchased from Himedia laboratories chemical co. For estimation of arsenic in aqueous solution the solution was directly estimated in visible spectroscopy by turbidity method. All the experiments were carried out using double Distilled water.

Preparation of chitosan nanoparticle: Chitosan nanoparticle was prepared by ionic gelation technique (Calvo *et al.*, 1997) briefly; Glacial acetic acid of 4 mL was diluted in 500 mL of distilled water. Then 4 g of chitosan was weighed and added little by little in the glacial acetic acid solution with continuous mixing of the solution using a magnetic stirrer. About 1 g of sodium tripolyphosphate was weighed and mixed with 100 mL of distilled water and after thorough mixing of the chitosan with glacial acetic acid solution; the sodium tripolyphosphate solution was added drop by drop on the chitosan mixture using a titration tube. The solution was continuously stirred using a magnetic stirrer and precipitates were formed on the bottom, after all the solution been added the solution was allowed to stir for another 20 min so that the precipitates will be well formed. After completion of stirring, the solution was taken and kept in deep freezer at 4°C for 24 h. The frozen solution was taken out after 24 h and allowed to melt, after melting the precipitates settled at the bottom were collected. Precipitates was taken and placed in a Petri dish and kept in hot air oven for 24 h for drying. The dried precipitates was then taken and crushed using a mortar and pestle, the powdered chitosan was obtained which is chitosan nanoparticle as shown in Fig. 1, which was stored in an air tight glass tube for further use.



Fig. 1: Chitosan nanoparticle

Preparation of immobilized chitosan nanoparticle (ICNP): After the preparation of chitosan nanoparticle it was immobilized the steps involved were about, 100 mL of distilled water was placed a heating mantle and was allowed to warm up and then 1 g of sodium alginate was weighed and added to the warm distilled water and stirred continuously until the sodium alginate was completely dissolved. Next 0.5 mg of the prepared chitosan nanoparticle was weighed and added to the prepared sodium alginate and mixed thoroughly. The prepared sodium alginate chitosan nanoparticle solution was then poured in to the titration tube. Later 2 g of calcium chloride was weighed and mixed with 100 mL of distilled water and the solution was kept underneath the titration tube. Then the titration tube was opened slowly so that drop by drop of the chitosan nanoparticle solution will fall on the calcium chloride solution. The beads were formed on calcium chloride solution, as shown in Fig. 2, after the formation of beads in calcium chloride solution it was stored in refrigerator for 2 days. The beads were then taken and washed with distilled water and stored for further use.

Morphology and structure characterization of chitosan nanoparticle: The morphology of chitosan nanoparticle was analyzed by Scanning Electron Microscope (SEM). The X-ray powder diffraction pattern of chitosan and chitosan nanoparticle was obtained by XRD measurement (XRDML), the sample was placed on anode material of copper (Cu) and the voltage used for measurement was 30 mA and 40 kV. The functional groups of chitosan and chitosan nanoparticle was analyzed by Fourier transform infrared spectroscopy (FT-IR) of Nexus 670/Thermo electron corporation, the sample was analyzed by KBr pellets and the beam splitter used for detection was XT-KBr. All the samples for SEM, XRD and FTIR were analyzed in Central Electro Chemical Research Institute (Karaikudi, Tamil Nadu).

Adsorption equilibrium experiments: The batch equilibrium experiment was carried out by using chitosan nanoparticle as adsorbent. A series of flasks containing Arsenic trioxide (As_2O_3) of



Fig. 2: Immobilized chitosan nanoparticle

various concentration was prepared by, First preparing stock solution of Arsenic trioxide (1 mg/100 mL) and from this stock solution various concentration of the Arsenic trioxide such as 4, 8, 12, 16, 20, 24, 28 and 32 mL was made up with 96, 92, 88, 84, 80, 76, 72, 68 mL of distilled water was prepared and adsorbent of 1 g was used as constant throughout the experiment. In pH studies was used for adjusting to 5.4, 6.7, 7.4 and 8.4 meanwhile for temperature the samples were placed on the water bath and temperature of the sample was adjusted to 30, 35, 40 and 60°C the samples were then placed on the shaker at agitation speed of 220 rpm for 24 h.

Adsorption of arsenic trioxide detected by UV- spectrophotometer: The adsorption of Arsenic trioxide was detected by turbidity method in which 2 mL of the solution was taken from each flask after 24 h and poured into test tube and was detected by turbidity method. The optical density of Arsenic trioxide was quantified at 880 nm under UV spectrophotometer 106; Systronics model. The amount of Arsenic trioxide adsorbed was determined by mass balance equation:

$$Q = \frac{V(C_0 - C_e)}{W}$$

where, Q is the sorption capacity (mg g^{-1}), C_0 and C_e are initial concentration (C_0) and final concentration (C_e) equilibrium at, V is the solution volume and W the mass of sorbent (g).

Adsorption isotherm: Using adsorption isotherm which are Langmuir isotherm and Freundlich isotherm the adsorption of arsenic by immobilized chitosan nanoparticle was confirmed.

Langmuir isotherm: The monolayer adsorption of arsenic (arsenic trioxide) onto chitosan nanoparticle was proved by the sorption isotherm proposed by Langmuir (1918). This model is based on two assumptions that the forces of interaction between adsorbed molecules are negligible and once a molecule occupies a site no further sorption takes place. Linear regression was used to

Table 1: Different linearized form of Langmuir and Freundlich equations

Isotherm	Linear regression	Plot	Parameters
Freundlich	$\text{Log}(C_e) = \text{Log}(K_F) + 1/n \text{Log}(C_e)$	$\text{Log}(q_e)$ vs. $\text{Log}(C_e)$	$K_F = \text{slope}$, $1/n = 1/\text{intercept}$
Langmuir type 1	$C_e/q_e = (1/K_L q_m) + (C_e/q_m)$	C_e/q_e vs. C_e	$K_L = \text{slope}/\text{intercept}$, $q_m = 1/\text{slope}$
Langmuir type 2	$1/q_e = (1/q_m) + (1/K_L q_m C_e)$	$1/q_e$ vs. $1/C_e$	$K_L = \text{intercept}/\text{slope}$, $q_m = 1/\text{intercept}$
Langmuir type 3	$q_e = q_m - (q_e/K_L C_e)$	q_e vs. q_e/C_e	$K_L = -1/\text{slope}$, $q_m = \text{intercept}$
Langmuir type 4	$q_e/C_e = K_L q_m - K_L q_e$	q_e/C_e vs. q_e	$K_L = -\text{slope}$, $q_m = \text{intercept}/\text{slope}$

C_e : Equilibrium concentration (mg L^{-1}), q_e : Amount of arsenic adsorbed at equilibrium (mg g^{-1}), q_m : Monolayer sorption capacity (mg g^{-1}), R^2 : Coefficient of determination and K_L : Langmuir isotherm constant (L mg^{-1})

determine the most fitted isotherm and the method of least squares has been used for finding the parameters of the isotherms. The Langmuir constants, monolayer sorption capacity q_m and K_L was calculated from the slope and intercept by the plots of four linearized form of Langmuir isotherm as shown in Table 1.

Freundlich isotherm: Freundlich isotherm (McKay and Allen, 1980) is used for determining non ideal adsorption on heterogeneous surfaces as well as multilayer adsorption and is expressed by the equation:

$$q_e = K_F C_e^{1/n}$$

where, C_e (mg L^{-1}) is the solute concentration in the liquid at equilibrium, q_e (mg g^{-1}) the amount of Arsenic adsorbed at equilibrium, K_F (mg g^{-1}) and $1/n$ (L g^{-1}) are the Freundlich constants related to adsorption capacity and adsorption intensity, respectively. The Freundlich isotherm has been derived by assuming an exponentially decaying adsorption site energy distribution.

The Langmuir equation was derived in four linearized types, the Langmuir constants q_m and K_L values can be calculated by plotting between type 1- C_e/q_e versus C_e , type 2 - $1/q_e$ versus $1/C_e$, type 3 - q_e versus q_e/C_e and type 4- q_e/C_e versus q_e , Langmuir isotherms, respectively. Similarly the Freundlich isotherm constants K_F and $1/n$ was calculated from the plot of $\text{Log}(q_e)$ versus $\text{Log}(C_e)$ and the R^2 value is used to find the best fitting isotherm a shown in Table 1. Linear method does not test whether the experimental data are linear. It assumes the experimental data were linear and predicts the slope and intercept that makes a straight line that predicts the best-fit of experimental equilibrium data. The linear method assumes that the scatter of points around the line follows a Gaussian distribution and the error distribution is the same at every value of X. The linear method just predicts the Y for the corresponding X. It considers only the error distribution along the Y-axis irrespective of the corresponding X-axis resulting in the different determined parameters for the four different types of linearized as well as for Freundlich isotherm the same experimental data.

RESULT AND DISCUSSION

The morphology of chitosan and chitosan nanoparticle by Scanning Electron Microscope (SEM). The surface morphology of chitosan and chitosan nanoparticle characterized by SEM indicates even layer of chitosan as shown in Fig. 3a and for chitosan nanoparticle crystal like structures which appears well dispersed on the surface which shows the crystal structure of amorphous chitosan has been broken up to less crystalline form as shown in

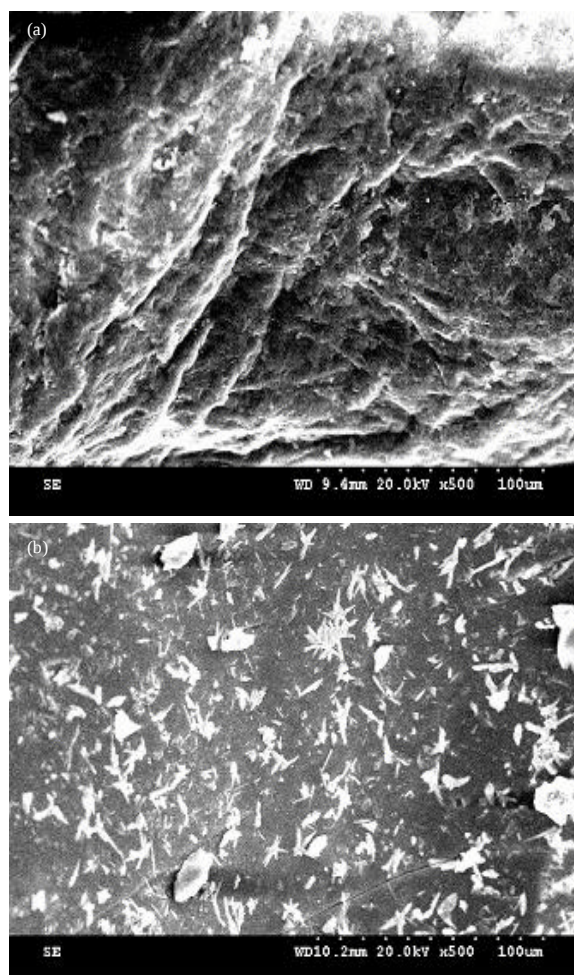


Fig. 3(a-b): Scanning electron microscope (x500) analysis of (a) Chitosan and (b) Chitosan nanoparticle

Fig. 3b. Chitosan nanoparticles structure is based on crosslinking, by ionic gelation method in which the positively-charged chitosan interact with negatively-charged tripolyphosphate at room temperature (De Campos *et al.*, 2001).

Analysis of surface functional groups by Fourier transform infrared spectroscopy (FT-IR): The surface functional group for adsorption of arsenic onto chitosan nanoparticle was analysed as shown in Fig. 4: The band from 3446.2 cm^{-1} - 3457.1 cm^{-1} belongs to N-H stretch and 1646.0 cm^{-1} N-H bend and CONH_2 groups (Xu and Du, 2003) they both correspond to primary amines group of chitosan whereas bands at 1645.3 cm^{-1} and 1543.4 cm^{-1} shows that amine group crosslinked with sodium tripolyphosphate molecules. Band from 2923.9 cm^{-1} - 2361.2 cm^{-1} belongs to O-H stretch which corresponds to carboxylic acid, bands 1316.0 cm^{-1} - 1384.9 cm^{-1} belongs to C-H bend (Kucherov *et al.*, 2003) they correspond to alkenes and bands at 1022.6 cm^{-1} - 1099.6 cm^{-1} belongs to C-N stretch which corresponds to amines. The major difference in the peaks after

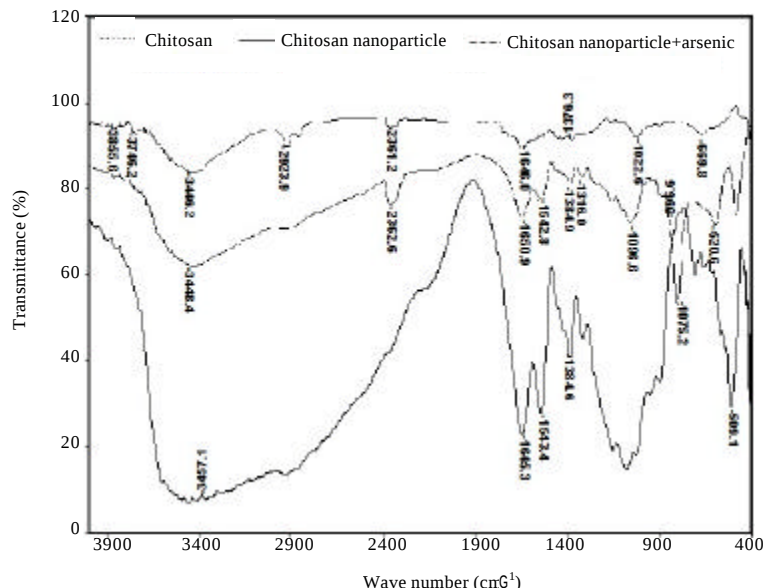


Fig. 4: Surface functional groups on adsorption of arsenic by chitosan nanoparticle analysis by FT-IR spectroscopy

adsorption of arsenic was that the bands at 1075.2 cm^{-1} belonging to C-N stretch of amines shifted slightly and turned sharper after arsenic adsorption to 1099.6 cm^{-1} . The bands at 1645.3 cm^{-1} and 1646.0 cm^{-1} showed an increase in wave number after arsenic adsorption to 1650.9 cm^{-1} . The bands at 3457.1 cm^{-1} corresponding to N-H stretch of primary amine group turns sharper and shifts to 3448.4 cm^{-1} due to arsenic adsorption whereas bands from 2361.2 cm^{-1} - 1376.3 cm^{-1} corresponding to O-H stretch and C-H bend shows a shift in band after arsenic adsorption. Thus Fourier transform infrared spectroscopy (FT-IR) shows the shift in peaks which confirms that chitosan nanoparticle adsorbed Arsenic.

Analysis of crystallinity by X-ray diffraction (XRD): There is one strong peak in the diffractogram of chitosan at 2θ at 20.19° their crystal lattice constant α corresponding to 4.39736 which is attributed to allomorphic tendon form of chitosan as shown in Fig. 5 and the peaks are sharper showing the presence of crystal structure. The peaks were also found in chitosan nanoparticle, three sharp peaks at 11.63° , 18.59° and 20.23° and their crystal lattice constants are 7.60582 , 4.77097 and 3.83291 and their peaks appear broader showing the crystal structure of amorphous chitosan has been destroyed by ionic cross linking of sodium tripolyphosphate as shown in Fig. 6, which confirms that chitosan nanoparticle are formed.

Equilibrium studies

Effect of concentration: The effect of concentration on the adsorption of Arsenic (Arsenic trioxide) using chitosan nanoparticle was studied by varying the concentration of chitosan nanoparticle such as 0.5, 0.8, 1 and 1.2% using the immobilization process of sodium alginate. After immobilization the immobilized beads were used to study the adsorption of arsenic. Various concentrations of arsenic ranging from $4\text{--}32\text{ mg mL}^{-1}$ were used for study; it was found that 1.0% immobilized chitosan nanoparticle showed higher adsorption capacity of about 23.7 mg g^{-1} whereas

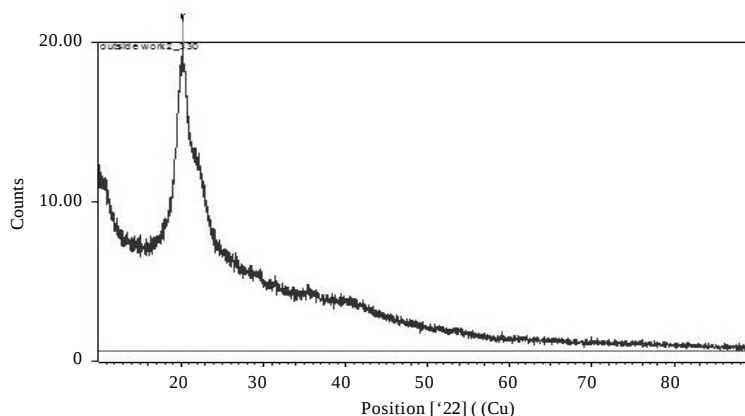


Fig. 5: XRD powder diffraction pattern of chitosan

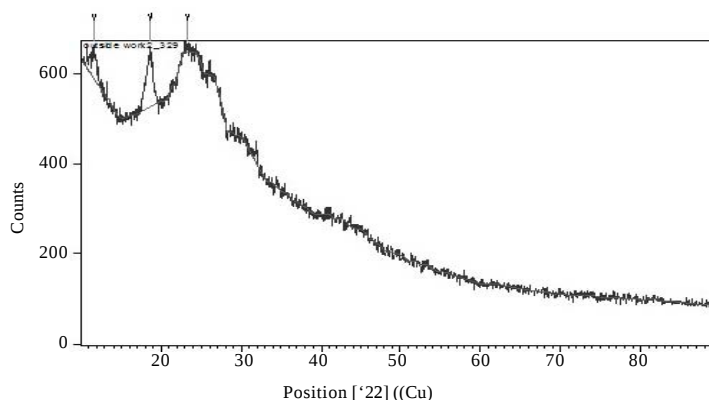


Fig. 6: XRD powder diffraction pattern of chitosan nanoparticle

the remaining showed lesser adsorption capacity 0.5% showed 21.7 mg g^{-1} , 0.8% showed 18.3 mg g^{-1} and 1.2% showed 16.7 mg g^{-1} adsorption capacity. Increase in initial concentration leads to increased uptake capacity (Guibal *et al.*, 2000). This is confirmed by Fig. 7, showing that increase in initial concentration of chitosan nanoparticle which is adsorbent leads to increase uptake capacity of the adsorbate arsenic. This might be due to increase in active sites with an increase in amount of adsorbent.

Effect of temperature: The effect of temperature on the adsorption of arsenic was studied by the increased adsorption concentration of immobilized chitosan nanoparticle of 1%. Various arsenic concentration ranging from $4\text{-}32 \text{ mg mL}^{-1}$ was used for study and the temperature was varied for each batch equilibrium studies they were 30, 35, 40 and 60°C , out of these the temperature 30°C showed higher adsorption capacity of about 26.0 mg g^{-1} whereas the remaining temperature showed lesser adsorption capacity, at 35°C the adsorption capacity was 20.0 mg g^{-1} , 40°C the adsorption capacity was 23.0 mg g^{-1} and at 60°C the adsorption capacity was 11.3 mg g^{-1} as shown in Fig. 8. It is found that arsenic adsorption decreased with increase in temperature, similar results were been reported in molybdate impregnated chitosan beads where the adsorption difference between 25°C and 40°C was significant ($p < 0.05$) but not dramatic (Chen *et al.*, 2008). The arsenic

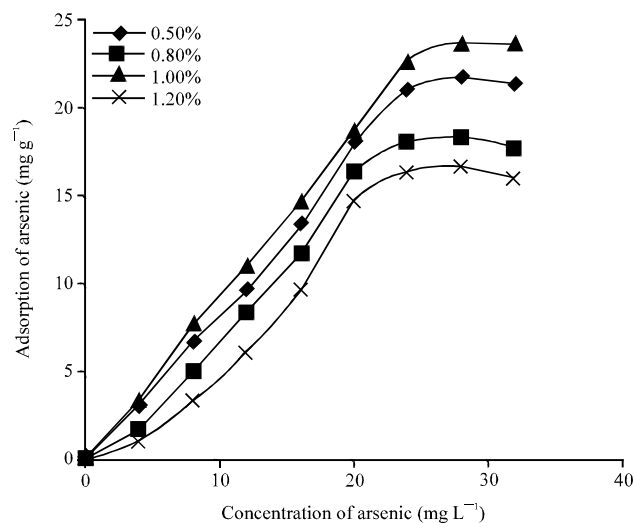


Fig. 7: Effect of concentration of immobilized chitosan nanoparticle on the adsorption of arsenic trioxide

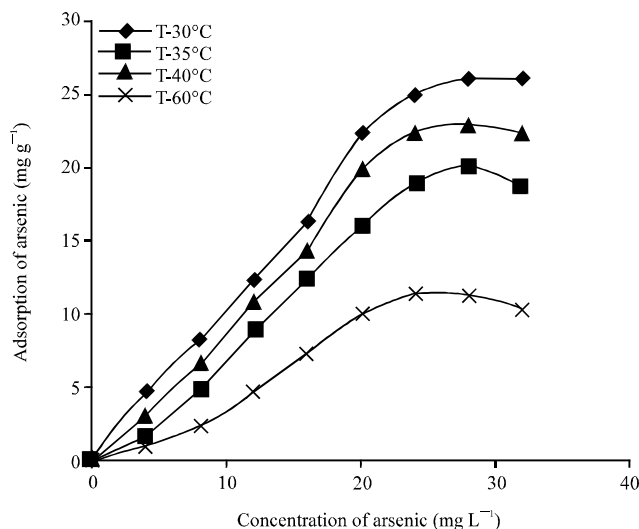


Fig. 8: Effect of temperature of immobilized chitosan nanoparticle on the adsorption of arsenic trioxide

adsorption onto chitosan nanoparticle is caused by exothermic reaction which shows that higher temperature resulted in lower amounts of saturated adsorption.

Effect of pH: The effect of pH on the adsorption of arsenic was studied by varying the concentration of arsenic ranging from 4-32 mg mL⁻¹ and batch equilibrium studies was conducted by varying the pH between 5.4 -8.4 as shown in Fig. 9. The equilibrium saturation point was noted, it was found that pH-7.4 showed higher adsorption capacity of about 26.3 mg g⁻¹ whereas pH-5.4 showed 17.3 mg g⁻¹, pH-6.7 showed 23.3 mg g⁻¹ and pH- 8.4 showed 20.6 mg g⁻¹ lesser adsorption capacity. It was found that adsorption capacity increased with increasing pH of the solution. The reason might

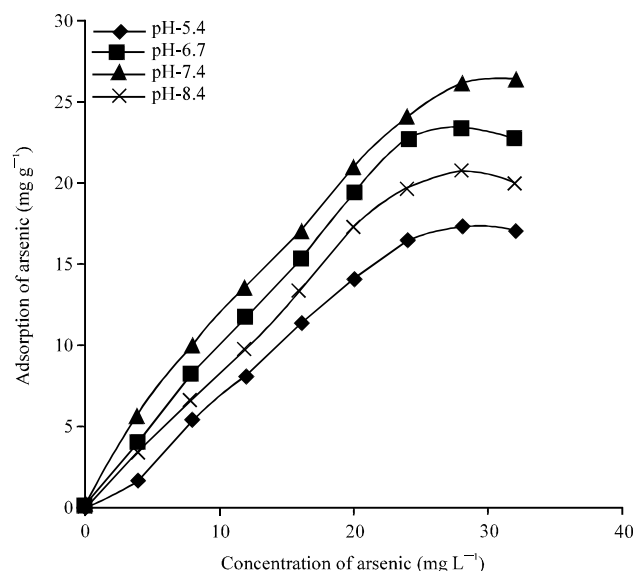


Fig. 9: Effect of pH of immobilized chitosan nanoparticle on the adsorption of arsenic trioxide

be at low pH the amine group and tripolyphosphate group of chitosan nanoparticle are protonated to varied degrees, leading to reduction in the number of binding sites and so the arsenic ion uptake is low, because arsenic is an anionic in nature which leads to higher degrees of protonation (Chu, 2002). When the pH is increased above neutral, competitor effect between the chitosan nanoparticle and arsenic ions is decreased leading to electrostatic repulsion, thus when the pH is increased above 7.4, the precipitation of arsenic trioxide occurs leading to decrease in sorption of chitosan nanoparticle (Dzul Erosa *et al.*, 2001). Therefore pH plays a critical role in the adsorption of metal ions. Another might be due to chitosan possessing positive charge have greater tendency to adsorb anions (Gao *et al.*, 2000). Chitosan adsorbs anionic species quantitatively as oxoanions or chloro complex anions of metals in sample solutions by an ion-exchange mechanism. This means that the interaction between NH_3^+ in chitosan and anionic species of the metal is chiefly electrostatic attraction in nature (Fu *et al.*, 1997). Arsenic adsorption is also found to be strongly depressed by phosphate ions (Kuchеров *et al.*, 2003) this might be also be a reason for decrease adsorption capacity at higher pH 8.4 because, if ions of phosphate will interact with arsenic leading to electrostatic repulsion. An another important factor involved in the adsorption of metal is porosity and ion exchange, the ion exchange process occurs through interaction between chitosan nanoparticle and arsenic ions but this process might be affected by pore clogging process in which the adsorbate (arsenic trioxide) tend to aggregate on the surface leading to blockage of the ion exchange mechanism (Nyembe *et al.*, 2009).

Adsorption isotherm: The easibility of arsenic (Arsenic trioxide) bound to chitosan nanoparticle was explained by Langmuir isotherm and Freundlich isotherm was determined, at various concentrations, Temperature and pH, was obtained. Using Langmuir isotherm the Langmuir isotherm constant (L mg^{-1}), q_m - concentration at equilibrium (mg g^{-1}) and R^2 was obtained and for Freundlich isotherm the Freundlich isotherm constant K_f (mg g^{-1}), $1/n$ (L g^{-1}) and R^2 was obtained as shown in Table 2. In Langmuir isotherm for concentration of chitosan nanoparticle the R^2 values reached ($0.9 > R^2 > 0.99$) in Type 2 and Type 3, for temperature the R^2 values reached ($0.9 > R^2 > 0.99$)

Table 2: Langmuir and Freundlich isotherm constants for Arsenic trioxide (As_2O_3) adsorption at different temperature, pH and concentration

		Langmuir isotherm parameter-linear method				Freundlich isotherm parameter
Factors		Type 1	Type 2	Type 3	Type 4	
Conc. (%)						
0.5	K _L	0.9936	0.0045	0.0087	0.0068	0.9936
	q _m	0.0821	163.93	83.338	110.529	0.0821
	R ²	0.9817	0.9951	0.7727	0.7784	0.9817
0.8	K _L	1.1788	0.0239	0.0247	0.0194	1.1788
	q _m	0.4399	17.0068	16.941	24.4588	0.4399
	R ²	0.9592	0.9709	0.7835	0.7835	0.9592
1.0	K _L	0.9726	0.0038	0.0028	0.0055	0.9721
	q _m	0.0515	217.391	311.06	151.20	0.0515
	R ²	0.9846	0.9931	0.9160	0.8649	0.9846
1.2	K _L	1.4060	0.0322	0.0306	0.0278	1.4060
	q _m	1.5924	7.1787	0.8379	10.5955	0.5924
	R ²	0.9652	0.9667	0.9081	0.9081	0.9652
Temp. (°C)						
30	K _L	0.0124	0.0109	0.0168	0.0122	0.8882
	q _m	92.5925	109.890	31.497	97.5984	0.0976
	R ²	0.8900	0.9953	0.9279	0.8437	0.9880
35	K _L	0.0925	0.0244	0.0147	0.0199	1.2079
	q _m	26.1780	15.8982	38.526	24.3065	0.2946
	R ²	0.8368	0.9704	0.7622	0.7663	0.9877
40	K _L	0.1473	0.0085	0.0147	0.0136	1.0240
	q _m	27.777	86.2069	48.540	53.6618	0.5394
	R ²	0.9544	0.9929	0.9197	0.9197	0.9392
60	K _L	0.5216	0.0205	0.0280	0.0235	9.0279
	q _m	2.1186	11.3250	8.5142	10.6340	0.0155
	R ²	0.9740	0.9909	0.9580	0.9645	0.9575
pH						
5.4	K _L	0.0093	0.0216	0.0064	0.0030	1.1250
	q _m	98.0392	18.6915	92.072	127.500	0.0375
	R ²	0.7062	0.9636	0.7364	0.7364	0.9608
6.7	K _L	0.0147	0.0067	0.0094	0.0030	0.8829
	q _m	58.4795	153.846	107.81	337.980	0.0147
	R ²	0.7082	0.9975	0.9347	0.8578	0.9800
7.4	K _L	0.0115	0.0265	0.0229	0.0233	0.7668
	q _m	91.7431	58.479	65.660	64.5031	0.2178
	R ²	0.8499	0.9982	0.9368	0.9322	0.9934
8.4	K _L	0.0207	0.0088	0.0144	0.0097	0.9188
	q _m	17.6678	222.22	63.533	91.1340	0.1199
	R ²	0.8892	0.9975	0.9315	0.7453	0.9814

correlation as shown in Fig. 12-14 with experimental data and for Freundlich isotherm the R^2 values reached ($R^2 > 0.9$) showing bad correlation with experimental data as shown in Fig. 10-15. Thus it was found, that at 0.5% concentration maximum adsorption capacity (q_m) 163.934 (mg g^{-1}), Langmuir isotherm equilibrium constant (K_L) 0.0045 (mg L^{-1}) and rate of coefficient determination (R^2) was 0.9951, at 30°C temperature the maximum adsorption capacity (q_m) 109.8901 (mg g^{-1}) and in Type 2 and Type 3 and for pH the R^2 values reached ($R^2 > 0.99$) in Type 2 which showed best

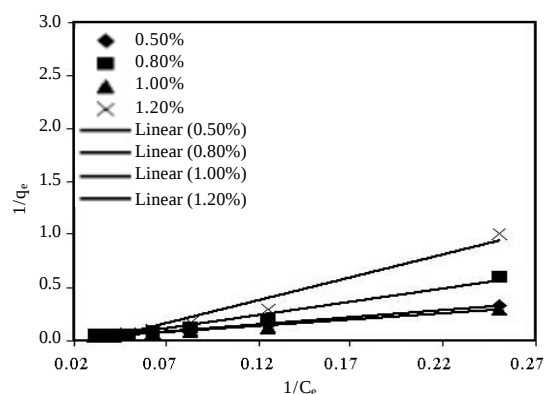


Fig. 10: Langmuir-2 isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different concentration

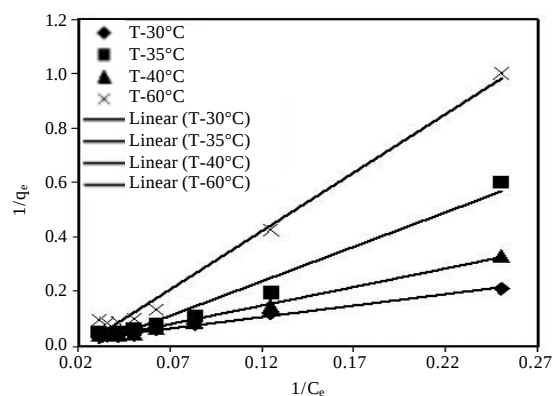


Fig. 11: Langmuir-2 isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different temperature

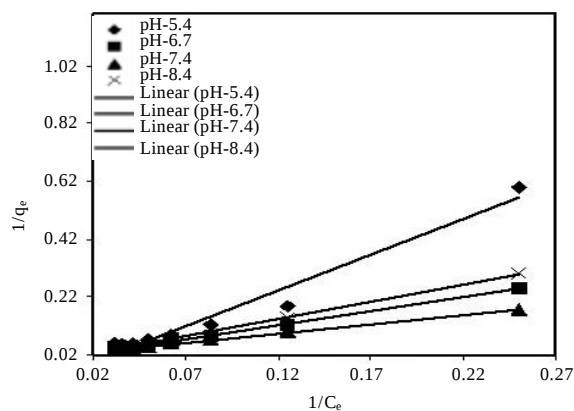


Fig. 12: Type 2 Langmuir isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different pH

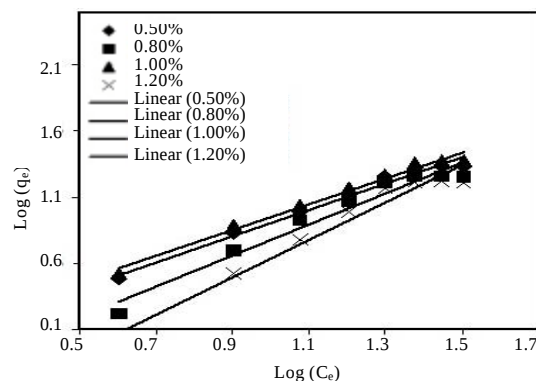


Fig. 13: Freundlich isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different concentrations

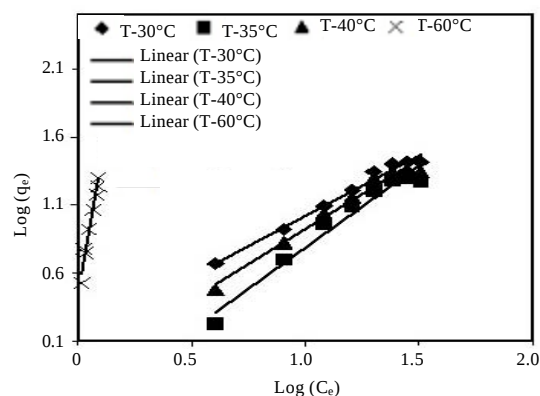


Fig. 14: Freundlich isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different temperature

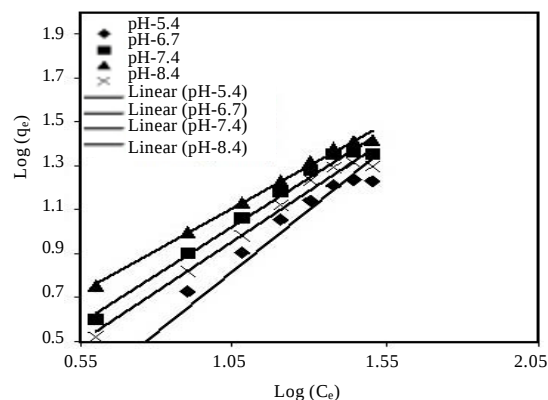


Fig. 15: Freundlich isotherm obtained using linear method for the adsorption of arsenic trioxide (As_2O_3) onto immobilized chitosan nanoparticle (IM-CH-Nanoparticle) at different pH

Langmuir isotherm equilibrium constant (K_L) $0.0109 \text{ (mg L}^{-1}\text{)}$ and rate of coefficient determination (R^2) was 0.9953 and at pH 8.4 the maximum adsorption capacity (q_m) $222.22 \text{ (mg g}^{-1}\text{)}$ and Langmuir isotherm equilibrium constant (K_L) $0.0028 \text{ (mg L}^{-1}\text{)}$ and rate of coefficient determination (R^2) was 0.9975 the values obtained. Thus Langmuir isotherm shows that the adsorption is a monolayer form of adsorption therefore arsenic adsorption onto chitosan nanoparticle is favourable. The results were compared with cadmium adsorption using various adsorbents such as green microalga, clarified sludge and grafted cellulosic fibers (Dekhil *et al.*, 2011), the result showed that adsorption was comparably lower, than the Present result for adsorption of arsenic by chitosan nanoparticle.

CONCLUSION

Chitosan nanoparticles were prepared by ionic gelation method using chitosan and sodium tripolyphosphate. The morphology of chitosan nanoparticle by scanning electron microscope (SEM) shows nanoparticle formation. Fourier transform infrared spectroscopy (FT-IR) reveal the functional groups of chitosan nanoparticles and the interaction with arsenic, the amine groups of nanoparticles provide adsorption sites for arsenic. Chitosan nanoparticles possess higher crystallinity than chitosan illuminated by XRD patterns. The experiments show that chitosan nanoparticles can adsorb arsenic from aqueous solution effectively and the adsorption capacity has been improved greatly dependent on Temperature and pH. The experimental data of the adsorption equilibrium from arsenic (Arsenic trioxide) solution correlate well with the Langmuir isotherm equation showing monolayer form of adsorption. The high sorption capacity of chitosan nanoparticles for arsenic (Arsenic trioxide) indicates a good adsorbent for the removal of heavy metals from polluted water.

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