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RESEARCH ARTICLE

Removal of chloride from ground water by Bio adsorption

Lokesh Kumar[1], S K Singh[2]

1. Research Scholar, Department of Environment Engineering Delhi Technological University, Delhi, India
2. Professor, Department of Environmental Engineering, Delhi Technological University, Delhi, India

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***Corresponding Author**

LOKESH KUMAR

Abstract

Chloride in concentration above 600 mg/l tends to give water a salty taste. The concentration of chloride content above 200 mg/l is considered objectionable. Presence of high quantity of chloride content in water resources indicate pollution due to human and industrial wastes and also from the earthen rocks in the subsurface. High chloride concentrations in freshwater can harm aquatic organisms by interfering with osmo-regulation, the biological process by which they maintain the proper concentration of salt and other solutes in their bodily fluids. Difficulty with osmo-regulation can hinder survival, growth, and reproduction. In large concentrations it can create problems to water supply line and human health. This paper deals with removal of chloride by using Bio adsorbent in batch study.

INTRODUCTION

Chlorides are not usually harmful to people; however, the sodium part of table salt has been linked to heart and kidney disease. Sodium chloride may impart a salty taste at 250 mg/L; however, calcium or magnesium chlorides are not usually detected by taste until levels of 600 mg/L are reached. Chlorides can corrode metals and affect the taste of food products. Therefore, water that is used in industry or processed for any use has a recommended maximum chloride level. Chlorides can contaminate fresh water streams and lakes. Fish and aquatic communities cannot survive in high levels of chloride increase. The chloride ion is negatively charge anion (Cl^-). It is formed when the elements chlorine gains an electrons or when a compound such as hydrogen chloride is dissolved in water or other polar solvent. Chloride salts such as NaCl are very soluble in water. It is an essential electrolyte located in all body fluids responsible for maintaining acid/base balance, transmitting nerve impulses and regulating fluid in and out of cells. Chloride is much larger than a chlorine atom, 167 & 99 pm respectively. The ion is colorless & diamagnetic. In aqueous solution it is highly solvated, being bound by the protic end the water molecules.

All natural waters contain chloride & sulphate ions. Their concentrations vary considerably according to the mineral content of the earth in any given area. In small amounts they are not significant. In large concentrations they present problems. Usually chloride concentrations are low. Sulfates can be more troublesome because they generally occur in greater concentrations. Low to moderate concentrations of both chloride and sulfate ions add palatability to water. In fact, they are desirable for this reason. Excessive concentrations of either, of course, can make water unpleasant to drink. Chloride is commonly found in streams & wastewater. Chloride may get into surface water from several sources including:

- Rocks containing chlorides;
- Agricultural runoff;
- Wastewater from small scale industries ; and
- Effluent wastewater from wastewater treatment plants.
- Produced water from gas and oil wells

A normal adult human body contains approximately 81.7 g chloride .On the basis of a total obligatory loss of chloride approximately 530 mg/day, a dietary intake for adults of 9 mg of chloride per kg of body weight has been recommended (equivalent to slightly more than 1g of table salt per person per day). For children up to 18 years of age, a daily dietary intake of 45 mg of chloride should be sufficient. A dose of 1g of sodium chloride per kg of body weight was reported to have been lethal in a 9 week old child. Chloride toxicity has not been observed in humans except in the special case of impaired Sodium chloride metabolism, e.g. in congestive heart failure. Healthy individuals can tolerate the intake of large quantities of chloride provided that there is a concomitant intake of fresh water. Little is known about the effect of prolonged intake of large amounts of chloride in the diet. As in experimental animals, hypertension associated with sodium chloride intake appears to be related to the sodium rather than the chloride ion.

2. *REMOVAL TECHNIQUES OF CHLORIDE*

2.1 NORCURE CONCRETE CHLORIDE REMOVAL SYSTEM:-

Norcure technology is one of the most important techniques which were taken up in order to address the problem of corrosion of the concrete due to the entry of chlorides. The Norcure process is an electrochemical method of removing chloride ions and drawing them out of the concrete. Using this method, concrete could be rejuvenated without the inconvenience and disruption of conventional demotion and repair, resulting in significant savings. The corrosive nature of sodium chloride (salt) is well known. It can bring about rust on automobiles, and wreak havoc on concrete, where corrosive concentrations of chlorides are often found. The chloride ions percolate deep into the concrete structures due the porous nature of concrete, eventually reaching the reinforced steel or rebar. Furthermore, after this, it begins to corrode the structure, and structures such as parking lots, highways and bridges become vulnerable due to its damaging effects. Once chlorides attack a structure, they quickly eat away at the reinforcing steel, causing cracks to appear. If left untreated, these chloride ions can cause concrete spalls, expose steel reinforcement bars and eventually reduce the structural integrity of the structure to dangerous Levels.

2.2 CHLORIDE REMOVAL USING ION EXCHANGE METHOD:-

Ion exchange works on the basic principle of charge based transport of ions. In a lab scale study on pulp and paper mill, several resins were tested for chloride removal. The resins were either free base forms or hydroxide base forms. The study concluded that two hydroxide ion based resins named IRN78 and 4400OH achieved approximately 50% and 70% chloride removal at a dose of 10 g / L and were the potential resins that may be used in the reduction in chlorides in Pulp and paper mill effluent.

2.3 ULTRA HIGH LIME WITH ALUMINIUM (ULHA) PROCESS:-

Lime softening serves as the favorite alternative for removing scale forming materials. However, the process does not remove silica, chloride or sulfates. A process named Ultra High Lime Softening was therefore devised, which successfully removed silica, but not sulfur and chlorides. Advanced methods are available for the removal of chlorides and sulfates, viz. Reverse osmosis, electro dialysis but lime softening is the cheapest alternative available for recycled cooling water. Also, the process like reverse osmosis is not only expensive, but also difficult to maintain. Occurrence of problems like membrane fouling may require frequent cleaning and production of brine in the form of reject creates a problem of effluent disposal. The Ultra High Lime with Aluminum process is an innovative technology which operates in two stages. The high pH and Calcium content in the first stage allows for removal of sulfate by precipitation as Calcium Sulfo-aluminate ($Ca_6\ Al_2\ (SO_4)_3(OH)_{12}$). Also, these conditions of the first stag allow the precipitation of chlorides as Calcium chloral- aluminates ($Ca_4\ A_{l2}\ Cl_2\ (OH)_{12}$). The cost economics of the process depicted that the capital cost is equivalent to the conventional lime process due to the fact that the same equipment is usable. Operating cost of the UHLA system is slightly higher due to the constant requirement to add aluminum. The sludge that is obtained contains almost 39% aluminum by weight.

2.4 CALCINED LAYER DOUBLE HYDROXIDES (CLDH) METHOD:-

On the basis of an effect known as Memory Effect, it was said that CLDH, within a certain temperature range, has the capacity to regain its original form. Therefore, a study was conducted in order to observe the capacity of

CLDH to assimilate chloride ions from aqueous solution. The study concluded that the assimilation of chloride ions by CLDH was consistent with Langmuir and Freundlich models.

2.5 *ELECTROCHEMICAL METHOD FOR THE REMOVAL OF CHLORIDES:-*

Electrochemical Chloride Extraction (ECE) is essentially a simple electrochemical process which consists of the use of basic principle of ion migration towards oppositely Charged poles. The apparatus contained an anode which was inserted in an electrolyte media. The setup was then applied on the concrete surface. The anode and the reinforcing steel were connected to two terminals of a direct current (DC) power supply such that the anode was positively charged. Due to the charge on the anode, the migration of the Chloride ions from the concrete to the anode field occurred, thereby reducing the chloride content in the concrete, particularly on and around the reinforced steel end. At the termination of the process, chloride free, highly alkaline concrete is obtained, which results in strong repassivation of the embedded reinforced steel and halting of the corrosion of the same. A study was conducted in order to observe the free chloride content in a concrete block during electrochemical chloride removal. It showed that, due to the free chloride removal, bound chloride is dissolved in order to reestablish the equilibrium between bound and free chloride The above literature review clearly indicates the need for research on the application of the biological substances for the chloride removal process. These processes may prove effective solutions for cost economic chloride removal. Therefore, the present paper studies the compatibility of the bio-sorption phenomena for chloride reduction.

2.6 ***BIO ADSORPTION***

Adsorption can be defined as a process in which atoms or molecules move from a bulk phase (that is, solid, liquid or gas) onto a solid or liquid surface. An example is purification of liquid/gases by adsorption where impurities are filtered by adsorption process onto the surface of a high-surface-area solid such as activated charcoal. Molecules that have been adsorbed onto solid surfaces are referred to as adsorbate, and the surface to which they are adsorbed as the adsorbent. The adsorption process can occur at interface between any two phases, such as, liquid-liquid, gas-liquid, gas-solid or liquid-solid interfaces. In the case of liquid-solid interfaces, three types of adsorption have been distinguished: (a) physical adsorption: due to Vander Waal's attraction, (b) chemical adsorption: due to formation of chemical bond and (c) exchange adsorption: due to electrical attraction of solute to the adsorbent. Chemical adsorption is characterized by high energies (> 40 kJ/mol) which are similar to those found between atoms within a molecule (for example, covalent bonds), strong localized bonds and is generally favored at higher temperatures. In physical sorption, the adsorbed molecule remains intact, but in chemisorptions the molecule can be broken into fragments on the surface, in which case the process is called dissociative chemisorptions. However adsorbed molecules are considered not to be free to move on the surface or within the interface and are referred to as "activated" adsorption (Weber, 1972) unlike physical adsorption. Most of the adsorption phenomena are coordination of the three forms of adsorption and are generally termed as sorption, which includes absorption too while desorption is the reverse process. The extent of adsorption depends on physical parameters such as temperature, pressure and concentration in the bulk phase, and the surface area of the adsorbent, as well as on chemical parameters such as the elemental nature of the adsorbate and the adsorbent. Low temperatures, high pressures, high surface areas, and highly reactive adsorbate or adsorbents generally favour adsorption. Biomass used as adsorbent after necessary activation by different methods is referred as Bio adsorption.

3. MATERIAL AND METHODS

3.1 USE OF CHLORIDE SAMPLE & GAJARGHAS (Parthenium) AS BIOADSORBENT

Natural Wastewater Sample with Chloride Concentration 1000 ppm was taken and the preliminary experiments were done with this sample. A plant known as grass / Gajarghas / Parthenium sps. / Congress (Belongs to the family asteraceae) was used as a bio-adsorbent. Before using, the Plant, it was dried & powdered (containing leaves and stem). The word 'Parthenium' has been derived from the Latin word 'Parthenice', meaning reputed medicinal merits. It has been speculated by scientists that the unique properties of this weed can be exploited for different purposes like activated carbon making, biomass generation, pesticide use etc.

Fig 1 Parthenium plant

Parthenium is considered to be one of the ten worst weeds in the world. Parthenium is an herbaceous annual or ephemeral member of the family Asteraceae. It can reach heights of up to 2 m in good soil, and attain flowering in less than 4– 6 weeks of germination. Seeds produced per plant can go up to 25000. Dispersion of the seeds occurs through various vectors like water, muddy surfaces, small animals, vehicles, machinery etc. Partheniumhas a variety of vernacular names, like Congress grass, White top, Star Weed, Carrot Weed, Gajar Ghaas (Hindi), Ramphool, feverfew etc. The pollen and seeds of these plants are known to be a major cause of asthma, and bronchitis. The weed shows the presence of toxins known as Sesquiterpene lactones, parthenin, phenolic acids such as caffeic acid, vanillic acid,anisic acid, panisic acid, and parahydroxy benzoic acid which are known to be lethal to humans as well as animals.

3.2 METHOD OF ACTIVATION OF BIO-ADSORBENT:

Sample collection was done on the basis of the health of the plant through visual observations. Young plants having a fresh green shoot and sizable stem thickness were selected. On collection, the specimens were washed with tap water and then distilled water. Further, for biomass collection, the specimens were subjected to drying in an oven at 100 ^{0}C for three days. Drying was followed by careful crushing of the specimen, and then sieving the mixture through a 500 micron sieve. The obtained biomass was used for the study. The biomass was added to the test solutions in the ratio of 0.10 g: 100 ml test solution. The pH of the sample was maintained at 7, and the chloride concentration at 100% of the initial wastewater solution. The mixture was then incubated in a rotary shaker incubator at 150 rpm and 300 ^{0}C for 60 minutes. On the termination of contact time, the solution was filtered using an ordinary filter paper. The sample was titrated for chloride content using the Argentometric titration method specified in the APHA handbook for water and wastewater analysis. The tests were repeated by carrying out variations in pH, by using different chloride concentration levels, and with variable contact times.

3.3BATCH MODE ADSORPTION EXPERIMENTS

Batch mode adsorption experiments were conducted at room temperature (23- 25 ^{o}C) except where mentioned. Predetermined quantities of adsorbent were added in the beaker and to achieve the degree of mixing and adsorption equilibrium, a magnetic stirrer was employed with speed adjusted at 100 rpm. A paddle stirrer was also employed with speed adjusted at 1000 rpm to check the difference in chloride removal due to different mode of physical mixing of bio-adsorbent ranging from pH 3- 11 which were well adjusted by using 0.1 N of HCl and NaOH whereas extreme pH were adjusted using 1 N acid/base solution. Addition of acid/base solution to adjust the pH never exceeded 1% of the total volume of the reactor.. The amount of Chloride adsorbed by adsorbent was calculated based on the difference of ion concentration in aqueous solution before and after adsorption according to the following equation:

$$q_t = \frac{(C_0 - C_t)V}{m}$$

where, q_t is the amount of chloride ions adsorbed per unit weight of adsorbent (mg/g) at time t, C_0 and C_t are the concentrations of chloride ions (mg/L) at initial time and at time t respectively, V is the initial volume of metal ions sample (L) and m is mass of adsorbent (g). When t is equal to the equilibrium contact time, $C_t = C_e$, $q_t = q_e$, then the amount of chloride ions adsorbed at equilibrium, q_e was calculated using equation as above.

3.4 ANALYTICAL TECHNIQUES

All analyses were carried out according to APHA (1998). Measurement of Chloride was carried out by Argentometric method. Drying and activation of bio adsorbent was done using a drying oven and a muffle furnace respectively. During adsorption experiment, degree of mixing was provided by employing magnetic stirrer or Jar test apparatus (Paddle Stirrer). Solution pH was measured by a digital pH meter. All weighing of reagents and adsorbents was carried out in an analytical weighing balance.

Table 2: Experimental design for batch studies with chloride and Bio-adsorbent

Experimental Set	Variable parameters	Control parameters	Purpose
1	pH	Concentration and Dose	Effect on absorption of chloride due to variation in pH
2	Time	Concentration and Dose	Optimization of time for removal of chloride
3	Dose(1,2,3,4,5,6 7g)	Initial Concentration of chloride: 100 to 1000 mg/L	Adsorbent dose test

4. RESULTS AND DISCUSSION

5.1 Effect of reaction pH in Batch study

Solution pH is one of the most important parameter to reveal the mechanism of adsorption. The effect of solution pH effect is firstly studied by conducting control experiment without any adsorbents. it’s clear that the solubility of chloride is consistent from pH range of 2- 12. Secondly, various pH range of chloride solution was contacted with Parthenium bio-adsorbent and the result is shown in fig 2.

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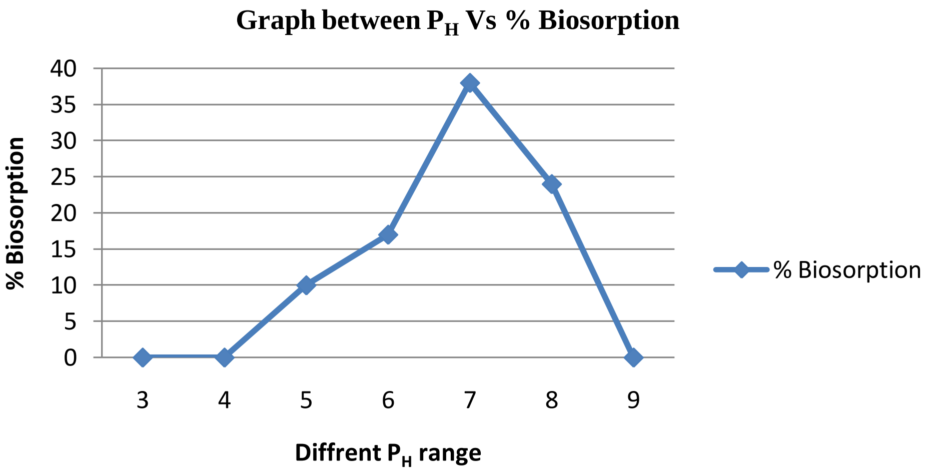


Figure 2: Effect of reaction pH on adsorption of chloride by Parthenium at various reaction pH (Initial Chloride: 100 mg/L; dose: 0.10g/100ml of solution) .

The best level of pH was found as pH 7, where the maximum absorption was observed by Parthenium.

4.2 EFFECT OF ADSORPTION TIME IN BATCH STUDY

The effect of initial chloride concentration on the adsorption was investigated varying initial chloride concentration in the range of 100–1000 mg/L. Batch experiments were performed at solution pH of 7.0 with 1 g/L bio- adsorbent. Removals of chloride ions (%) with time at a fixed initial chloride concentrations and amounts of chloride adsorbed are shown in Fig 3. and 4 respectively. The equilibrium between chloride and bio-adsorbent was attained within 5 minutes at initial chloride concentration of 100 mg/L and 20 minutes for all higher chloride concentrations. Equilibrium time increased to 90 minutes for almost all chloride concentration to 1000 mg/L and was constant beyond that. The chloride adsorption yield decreased with increase in initial concentration of chloride. At chloride concentration of 100 mg/L, 88% removal was achieved. When initial chloride concentration was increased to 1000 mg/L, chloride removal decreased to 40%. However, chloride uptake increased with increase in initial chloride ion concentration Fig 4. At initial chloride concentrations of 100 mg/L, chloride uptake was 84 mg/g and increased to 400 mg/g at

initial chloride concentration of 1000 mg/L. The reason was probably with increase in concentration, the number of Chloride ions increased and so chances of contact between chloride ions and adsorption sites also increased. This was responsible for higher chloride uptake by unit amount of adsorbent.

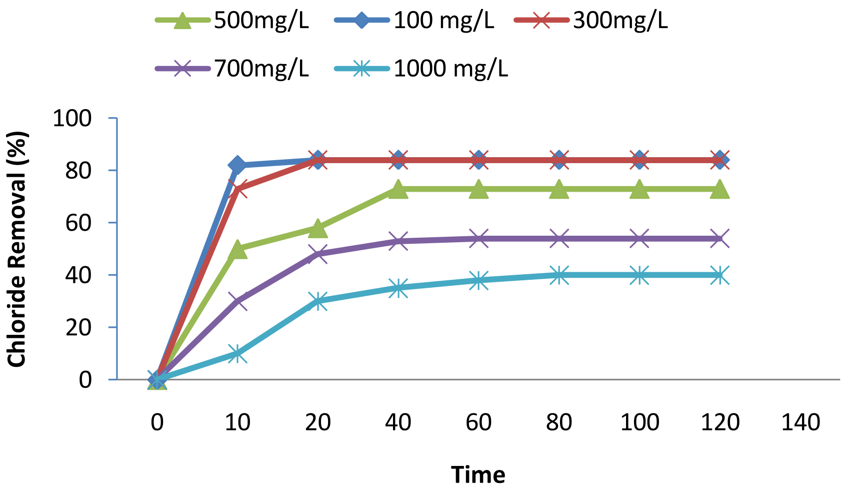


Figure 3: Effect of reaction time on adsorption (%) of chloride by bio-adsorbent at various initial concentration of chloride (Reaction pH: 7; dose: 1 g/L)

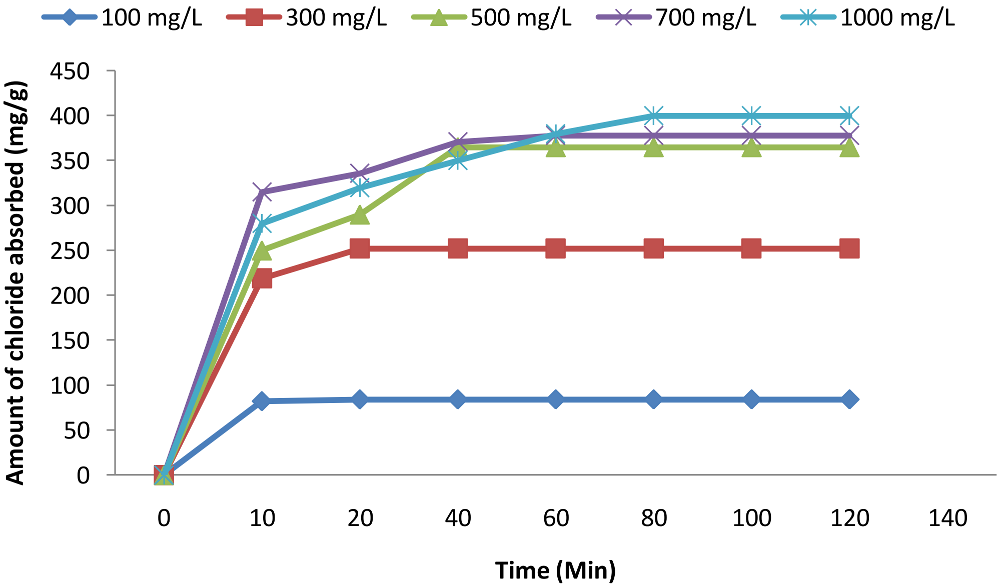


Figure 4: Effect of reaction time on adsorption of chloride (mg/g) by Parthenium bio Adsorbent at various initial concentration of chloride (Reaction pH: 7; dose: 1 g/L)

This process of chloride adsorption was also conducted with a fixed concentration of chloride to. 1000 mg/L as per the actual water sample concentration. The adsorbent dose was kept to 2 g. with a fixed pH of 7. The performance of the absorbent is as shown in the graph below. The contact time was kept to 10 min. to 240 min. with 500 rpm rotating system. This graph shows increased % of bio-adsorption with increased contact time.

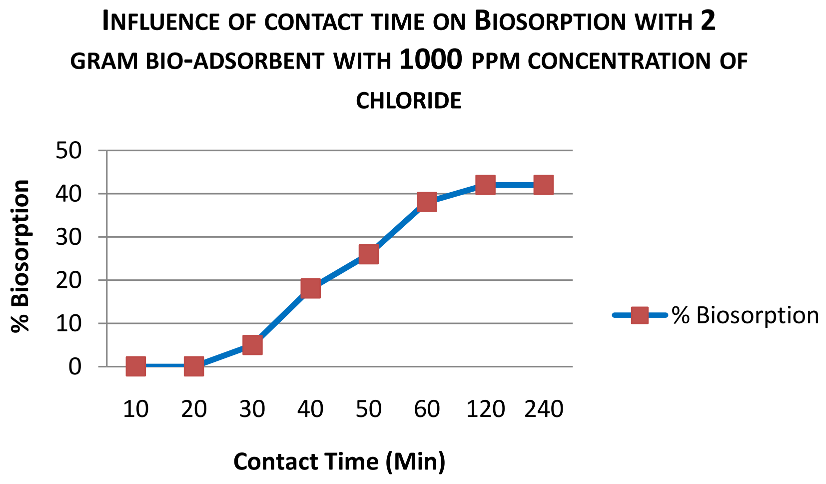


Figure 5: Effect of reaction time on adsorption (%) of chloride by bio-adsorbent at 1000 mg/L initial concentration of chloride (Reaction pH: 7; dose: 2 g/L)

4.3 EFFECT OF ADSORBENT DOSE

Effect of adsorbent dose on chloride uptake was studied by varying the adsorbent dose from 1 g/L to 7 g/L for only one fixed initial chloride concentration of 1000 mg/L. Initial pH was adjusted to 7. Chloride removal (%) and uptake with adsorbent dose for fixed chloride concentrations are shown in Fig.6.. It was observed that chloride removal (%) for fixed concentrations increased from 20% to 60% with increase in the adsorbent dose. The number of Chloride ions of adsorption sites or surface area increases with the weight of the adsorbent and hence results in a higher percent of metal removal at a high dose.

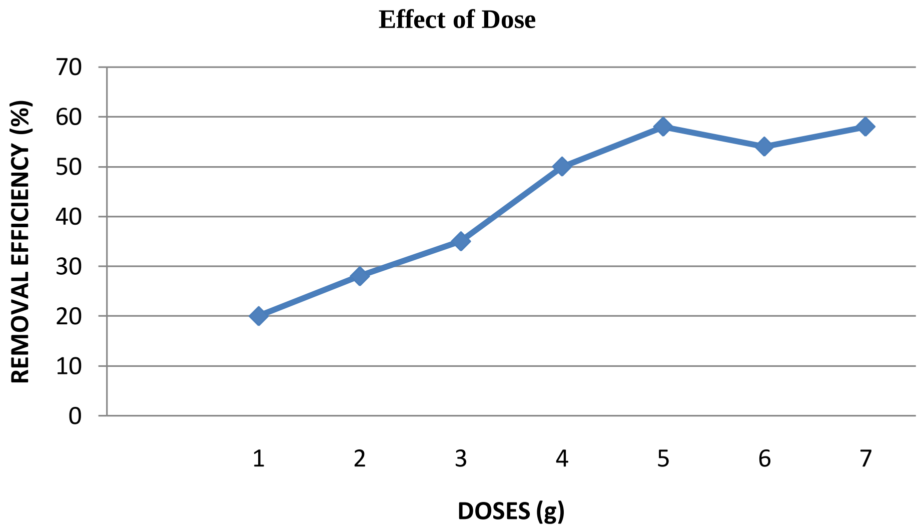


Figure 6: Removal (%) of chloride with varied dose of bio-adsorbent

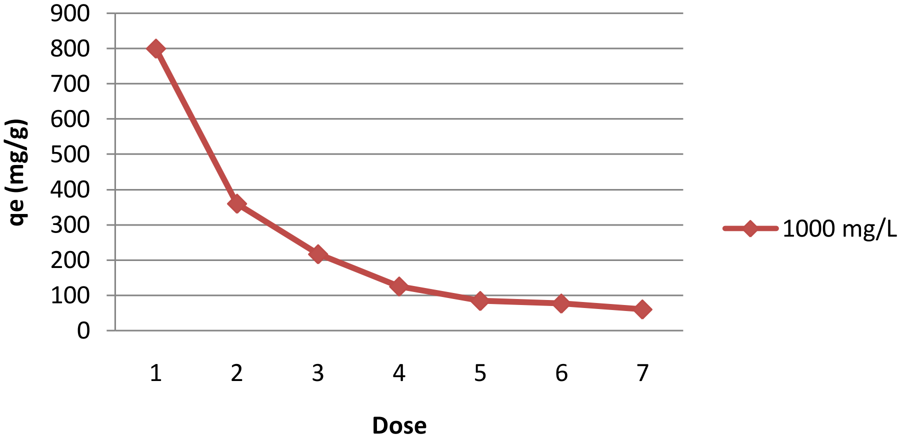


Figure 7: Plot of Removal (q_e) for chloride Vs dose of Parthenium

4.4ADSORPTION ISOTHERM

Adsorption isotherm is a mathematical model or functional expression to depict the distribution of solute between the solid and liquid phase at equilibrium at a constant fixed temperatures. The isotherm model relates the amount of solute adsorbed per weight of adsorbent (q_e), with amount of solute retain in solvent (C_e) at equilibrium. Commonly, the amount q_e increase with increase in C_e value, but not in direct proportion. Several mathematical model or isotherms were developed based on certain assumptions. Langmuir isotherm, Freundlich isotherm, Langmuir-Freundlich isotherm, BET isotherm, Temkin, Redlich–Peterson etc. are some of the well known models out of which Langmuir and Freundlich isotherm are the commonly and mostly applied models in chloride adsorption from aqueous solution.

4.4.1 LANGMUIR ISOTHERM

Langmuir isotherm is based on the following assumptions: (a) each surface site can be singly occupied, (b) there are no lateral interactions between adsorbed species, (c) the enthalpy of adsorption is independent of surface coverage and (d) energy of adsorption is constant thus creating homogeneity of energy on the surface (there is dynamic equilibrium between the adsorption and desorption processes).

$$K_d\theta = K_a C_e(1-\theta)$$

or, $\theta = \dfrac{K_a C_e}{K_d + K_a C_e} = \dfrac{bC_e}{1+bC_e}$

The adsorption coefficient $b = \dfrac{K_a}{K_d}$, is related to the enthalpy of adsorption (ΔH) by

$$b = b_0 \exp^{-\Delta H/RT}$$

where b_0 is constant related to entropy, R is the universal gas constant, T is the temperature (^{0}K) (Voice and Weber 1983).

As q_e is proportional to θ, therefore, equation (A) can be written as,

$$q_e = \frac{bQ_m C_e}{1 + bC_e}$$

where q_m is the maximum adsorption for a complete monolayer coverage. Equation (B) can be rearranged in variety of linear forms.

$$\frac{C_e}{q_e} = \frac{1}{Q_m b} + \frac{C_e}{Q_m}$$

$$\frac{1}{q_e} = \frac{1}{Q_m} + \frac{1}{bQ_m C_e}$$

$$q_e = Q_m - \frac{q_e}{bC_e}$$

4.4.*2* *FREUNDLICH ISOTHERM*

Freundlich model or van Bemmelon equation has been developed for adsorption system with emphasis on two factors, namely the lateral interaction between the adsorbed molecules and the energetic surface heterogeneity. The equation has the general form (Freundlich 1906)

$$q_e = K_f C_e^{\frac{1}{n}}$$

but it is well cited in logarithmic form as

$$log q_e = log K_f + \frac{1}{n} log C_e$$

where K_f and n are empirical constant. Here, K_f α RT nb exp(ΔH/RT). Equation (F) suggests that with increase in C_e, adsorption capacity (q_e) would increase without restriction, which is practically impossible. The model may simulate concentrations far outside the range of the defining batch experiment. Extrapolating equation (F) into such concentration regions hence may give results of unknown, but potentially very large error. However in practical situation, adsorption process are sufficiently dilute and one never encounters the region where Freundlich equation breaks down for this region and Freundlich isotherm equation implies that the energy distribution of adsorption site is of exponential (Cooney 1999).

In order to identify the best fit isotherm model, Chi square test was done by the following equation G. (Ho et al, 2005)

$$\chi^2 = \Sigma \frac{(q_e - q_{em})^2}{q_{em}}$$

Where, q_e is the experimental data of the equilibrium chloride uptake (mg/g) and q_{em} is the equilibrium uptake calculated from isotherm models (mg/g).

The linear plots of Langmuir isotherm is shown in Fig. 8 with $1/C_e$ Vs $1/q_e$. Also the linear plot of Freundlich isotherm with In(C_e) Vs In (q_e) is plotted in Fig.9. The correlation coefficients and the coefficients are shown in Table 5. It shows that Langmuir isotherm fitted experimental data better than the Freundlich model as it showed larger R^2 value as compared to the Freundlich model. The Langmuir curves had good linearity (Correlation coefficient > 0.99) for Bio adsorbent doses indicating strong binding of chloride ions to the surface of Parthenium during adsorption. The Langmuir monolayer capacity (a) or maximum adsorption capacity is observed to be 24.39 mg/g. The adsorption equilibrium parameter b, which reflects quantitatively the affinity between the adsorbent and the adsorbate, is 0.0149 L/g. The essential features of the Langmuir isotherm can be expressed in terms of a dimensionless constant separation factor or equilibrium parameter (R_L), which is defined by the following relation.

$$R_L = \frac{1}{1 + bC_0}$$

(H)

Where b is the Langmuir constant C_0 is the initial liquid phase chloride ion concentration and for favorable adsorption $0 < R_L < 1$. Separation factor RL indicates the isotherm shape accordingly.

RL >1, Unfavorable
RL=1, Linear
RL lies between 0 and 1, Favorable
RL=0, Irreversible.

Further the plot of comparison of q_e value of experimental and predicted through both Langmuir and Freundlich isotherms is shown in Fig. 10.

Table2 : Coefficients of Langmuir and Freundlich's isotherm

Langmuir				Freundlich			
R^2	a (mg/g)	b (L/mg)	λ^2	R^2	K_f	N	λ^2
0.9901	24.39	0.0149	0.64	0.9364	2.7604	2.9913	1.16

Table 3 : Observation table during batch study

Co (mg/L)	**Ce (mg/L)**	**1/Ce**	**LogCe**	**InCe**	**Qe**	**1/Qe**	**logQe**	**InQe**	**Ce/Qe g/L**	**qe(exp)**	**Qe (Lang)**	**Qe (Fre)**
100	28	0.035714	1.447158	3.332205	7.2	0.138889	0.857332	1.974081	3.888889	7.2	7.1888668	8.409449
200	72	0.013889	1.857332	4.276666	12.8	0.078125	1.10721	2.549445	5.625	12.8	12.633952	11.53158
300	138	0.007246	2.139879	4.927254	16.2	0.061728	1.209515	2.785011	8.518519	16.2	16.418883	14.33323
400	232	0.00431	2.365488	5.446737	16.8	0.059524	1.225309	2.821379	13.80952	16.8	18.924879	17.0516
500	302	0.003311	2.480007	5.710427	19.8	0.050505	1.296665	2.985682	15.25253	19.8	19.961632	18.62297
600	380	0.002632	2.579784	5.940171	22	0.045455	1.342423	3.091042	17.27273	22	20.734372	20.10964
700	490	0.002041	2.690196	6.194405	21	0.047619	1.322219	3.044522	23.33333	21	21.456314	21.8935
800	579	0.001727	2.762679	6.361302	22.1	0.045249	1.344392	3.095578	26.1991	22.1	21.860492	23.14974
900	681	0.001468	2.833147	6.523562	21.9	0.045662	1.340444	3.086487	31.09589	21.9	22.205427	24.44014
1000	750	0.001333	2.875061	6.620073	25	0.04	1.39794	3.218876	30	25	22.389926	25.24153

Table 4: Coefficients of Isotherms

χ2 of Lengmuir	**χ2 of Freundlich**	**A**	**b**	**Kf**	**N**	**R_L**
1.72149E-05	0.203162104	24.39	0.014926	2.760467	2.991325	0.401186
0.002154067	0.125694191	24.39	0.014926	2.760467	2.991325	0.250928
0.002957397	0.215112022	24.39	0.014926	2.760467	2.991325	0.182554
0.268756607	0.003768144	24.39	0.014926	2.760467	2.991325	0.143463
0.001319433	0.069969707	24.39	0.014926	2.760467	2.991325	0.118161
0.072809692	0.162430223	24.39	0.014926	2.760467	2.991325	0.100446
0.009915341	0.038016173	24.39	0.014926	2.760467	2.991325	0.08735
0.002595655	0.049861887	24.39	0.014926	2.760467	2.991325	0.077275
0.004259605	0.294626176	24.39	0.014926	2.760467	2.991325	0.069283
0.272499434	0.002333381	24.39	0.014926	2.760467	2.991325	0.06279
0.637284446	1.164974007					

Fig 8-Langmuir Adsorption Isotherms

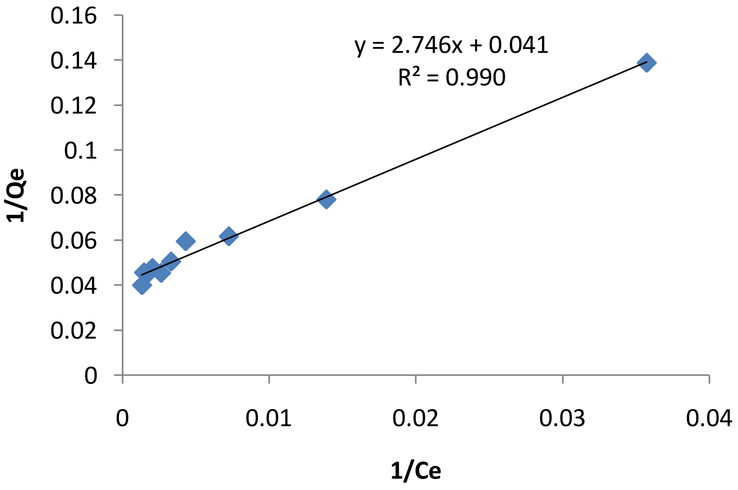
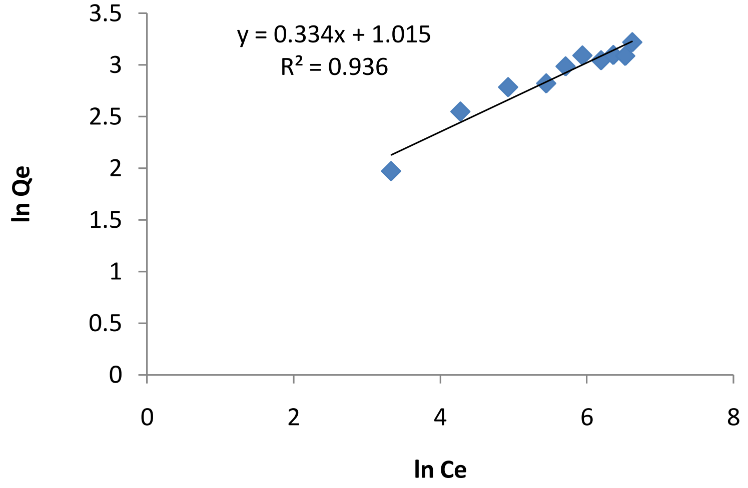


Fig 9-Freundlich adsorption Isotherm



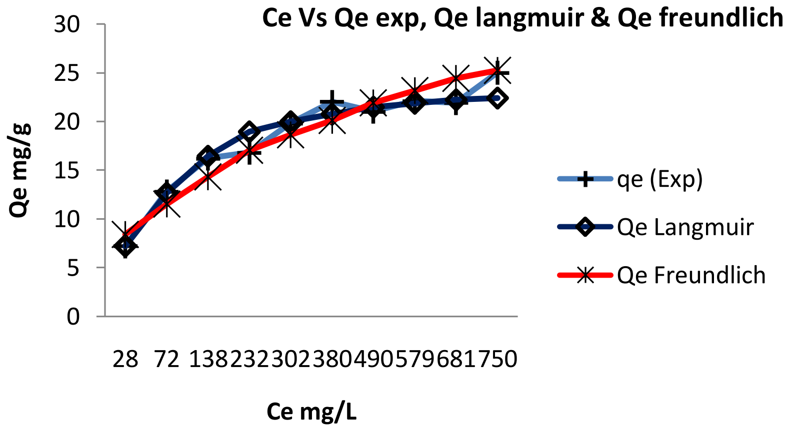


Figure 10: Comparison between experimental q_e and predicted q_e value of Langmuir & Freundlich's isotherm

5.CONCLUSIONS

Following conclusions are drawn from the study.

1. The Parthenium may be used for removal of chloride from the ground water. The Parthenium is showing maximum absorbance at pH 7.
2. During the variation in the adsorbent dose, corresponding increase in the adsorption was noted with increase in the dose in the solution.
3. The batch process results were best suited in to the Langmuir Isotherm instead of Freundlich Isotherm. R^2 of Langmuir is 0.99 and Freundlich is 0.93.
4. Freundlich isotherm 'n' value of 2.99 which is less than 10 and greater than 0 suggest the favourable adsorption of chloride by Parthenium.
5. The performance of Parthenium when subjected to actual water decrease by 15-25% due to the presence of other co-ions.

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