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Removal of Vanadium (V) from water by adsorption using GAC loaded with ethylene di-amine tetra acetic acid (EDTA) and nitrilo tri-acetic acid (NTA)

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ABSTRACT

The studies on removal of Vanadium were conducted using Granulated Activated Carbon (GAC) in combination with Chelating agents. Ethylene di-amine Tetra Acetic Acid (EDTA) and Nitrilo Tri Acetic Acid (NTA) at 25°C. The adsorption Efficiency was studied in the pH range of 2-8. The results reveals that Langmuir and Freundlich isotherms are followed during adsorption process with the chelating agents under study. The granulated activated carbon (GAC) loaded with Ethylene di-amine tetra acetic acid (EDTA) shows greater adsorptive capacity as compared to granulated activated carbon (GAC) loaded with the chelating agent, Nitrilo-Tri-acetic acid (NTA).

Key words: Pentavalent Vanadium, Langmuir and Freundlich isotherm, Chelating agent, Water pollution, Activated Carbon.

INTRODUCTION

The Twentieth century started with an extensive damage to the natural resources[1]. Unplanned industrialization, urbanization, pollution explosion, change in life-style, overexploitation of natural resources, commercial establishment and modem agricultural practices have degraded the quality of environment. The main effects being faced are:

- Continental invasion of air and water.
- Marine pollution through waste discharge.
- Release of variety of chemical and biological sontaminants into the water bodies, on land and in air.
- Ground water pollution.
- Acid rains and nuclear fallout.

These effects are not only covering the pollution of environment but also are responsible in reating genetic erosion in plants, animals including human beings and microorganisms. Water is a prime natural resource and is a basic human need. The availability of adequate water supply in terms of its quality and quantity is essential for the existence of life.

Water is available in nature as surface water and ground water through the self purification mechanism like physical, chemical and microbiological processes at natural bodies, are carried out in nature. However, natural water is rarely suitable for direct consumption to human beings. Rapid industrialization and population growth resulted to generation of large quantities of waste water and causing problem of their disposal. Industrial waste constitutes the major source of various kinds of metal pollution in natural water. The presence of heavy metals in the environment has been of great concern because of their increased discharge, toxic nature and other adve4rse effects on the receiving streams. When the concentration of toxic metal ions exceed tolerance limit, they may become real health concern[2]. There is an immediate need to introduce cleaner technologies to minimise the pollution and to protect the degrading environment. It is not possible to achieve zero waste discharge, but it is an essential to treat the waste.

Among the toxic heavy metal ion which present in potential health hazard to aquatic animals and human like Pb, Cd, Cr, V, Bi and Mn are important.

The maximum tolerance limit for vanadium for public water supply are 10 mg/L Toxicity of metal depends on the type of metal, dose and the ionic form.

Toxicity of vanadium[3] include rhinitis, blood discharge, an itching and burning sensation in the throat, dry cough with small amount of viscid sputum, general weakness. The moderate toxicity includes respiratory tract infection, bronchitic, bronchopneumonia, Disorder of the nervous system and tremor of the finger and hands. In animals, it affects the kidney, nervous, respiratory, cardiovascular and immune system.

Literature survey reveals that, there are many methods namely coagulation, precipitation, ion exchange and adsorption, for removal of vanadium metal ions from aqueous medium. However, adsorption is an easy and economical process for removal and retrieval of cation from aqueous medium. Efficiency of adsorption process mainly depends on nature of adsorbent, adsorbate, pH, concentration, temperature, time of agitation etc. There is a need to enhance the adsorptive power of an adsorbent by using the same with various type of chelating agents.

These cheap and efficient adsorbents can carry to cater the need of population in the rural areas and the population in the industrial area where safe drinking water is not available. In the present study, an attempt has been made to increase the adsorption efficiency of G. A. C. by using chelating agents namely EDTA and NTA.

Methodology

Preparation of Adsorbents (Granular Activated Carbon)

The commercially available activated Carbon was selected as an adsorbent for the present study. The carbon was sieved through a mesh size (-12 × 18) (m/s Jayant Test sieves, Mumbai) and washed with distilled water, several times until the leachate was free from any suspended impurities. The washed sample was then dried in an oven at 100-110°C and stored in a calcium chloride desiccators until use.

Batch Study

The dried amount of 0.5 gms. of GAC was taken in 1000 ml in round bottom flask and synthetic solution (200 ml) containing various concentrations of various amount of vanadium ion was added and was stirred using remistrirrer at 1000 r.p.m. in a thermostat maintained at (25 ± 1)°C, for six hours.

Similarly 0.5 gms. of GAC was taken in shaking bottle and 100 ml of 0.002 M of ligand (EDTA or NTA) was adsorbed on it. This process of fixing a ligand (EDTA or NTA) on GAC is denoted as "Loading of GAC". Then the bottles were shaken at room temperature (25 ±1°C). Once the loading of GAC with ligand (EDTA or NTA) was done, synthetic solution (200 ml) containing various concentrations of vanadium ions was added to the loaded activated carbon in 1000 ml round bottom flask, and stirred using remistrirrer at 1000 r.p.m. in thermostat maintained at the temp (25 ± 1°C), for six hours.

The initial and final concentrations of metal ion Vanadium (V) \was determined by spectrophotometry using hydrogen peroxide method and measured absorbance at 450 nanometer. The spectrophotometer, Systronic (model 140) was used to measure the concentration of Vanadium (V) ions.

RESULTS AND DISCUSSION

Equilibrium adsorption isotherms for Ce, Versus q_e, plotted for activated carbon are shown in Fig. 1. The adsorption capacity in mg/L was calculated from the equation.

$$qe = (Co\text{-}Ce)V/M$$

Where,
Co is the initial concentration of vanadium (V).
Ce is the concentration of vanadium (V) at equilibrium in mg/L.
V is the volume of solution in litre and
M is the mass of adsorbent in grams.
Similarly equilibrium adsorption isotherm for Ce Vs qe plotted for EDTA and NTA adsorbed on GAC is shown in Fig. 2.

The adsorption capacity was calculated from the equation.

$$q_e=(Co-Ce)V/M$$

Where,

q_e = represents the maximum amount of vanadium (V) that millmole of EDTA and NTA can hold.
Co = Initial concentration of vanadium (V) ion in solution in mg/L.
Ce = Concentration of Vanadium (V) ion at equilibrium in solution in mg/L.
V = Volume of solution in litre and
W = Millmole of ligand (EDTA or NTA).

Adsorption isotherms

Equilibrium isotherms was studied for both Langmuir and Freundlich isotherms. The results are shown in Figures 3, 4 and 5 which, illustrate the plot of Langmuir and Freundlich isotherms of activated carbon loaded with EDTA and NTA for Vanadium. The saturated monolayer can be represented by:

$$q_e = \frac{Q^0.b.Ce}{1+b.Ce}$$

The linearsed form of the Langmuir isotherms is

$$\frac{1}{q_e} = \frac{1}{q^0 b} \times \frac{1}{Ce} + \frac{1}{Q^0}$$

where Q° and b are Langmuir constants. The plot of 1/Ce Vs 1/qe was found to be linear, indicating the applicability of Langmuir model. The parameters Q° and b have been calculated and presented in Table 1 the Langmuir constant Q° is a measure of adsorption capacity and b is the measure of energy of adsorption. In order to observe whether the adsorption is favourable or not, a dimensionless parameter 'R' obtained from Langmuir isotherm is.

$$R = (1 + b \times Cm)^{-1}$$

where b is Langmuir constant and Cm is maximum concentration used in the Langmuir isotherm. The adsorption of Vanadium on G. A. C. loaded with ligand is a favourable process as "R" values lie between zero to one. Coefficients of co-relation (r) are also shown in Table 1.

The applicability of Freundlich isotherm was also tried using the following general equation.

$$q_e = k.C_e B$$

linearised form of this equation is

$$\log q_e = B.\log Ce + \log k$$

where B and k are Freundlich constant. These constants represent the adsorption capacity and the adsorption intensity respectively.

Table 1: Isotherm Constants

S.	Adsorbent	Langmuir constants				Freundlich constants'		
No.		Q°	b	R	r	k	B	r
1.	GAC	4.9900	0.0708	0.2618	0.9546	1.228	0.2993	0.9477
2.	GAC Loaded with EDTA	14.1043	0.5998	0.0401	0.9734	9.840	0.0925	0.9675
3.	GAC loaded with NTA	24.7524	0.04151	0.3444	0.9404	1.683	0.6398	0.9217

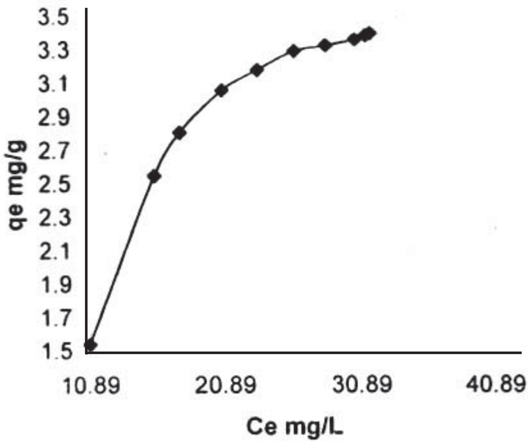

Fig. 1: Equilibrium Adsorption isotherm for GAC

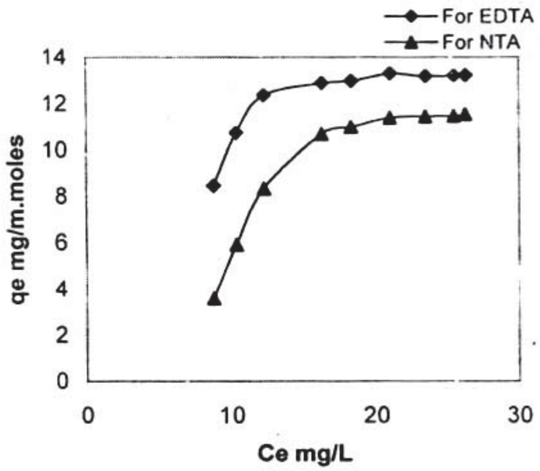

Fig. 2: Equilibrium adsorption isotherm

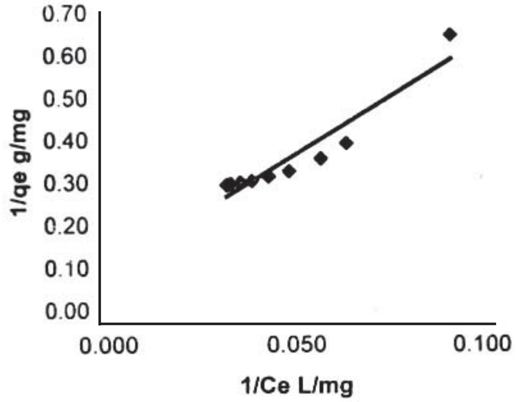

Fig. 3: Langmuir isotherm for GAC

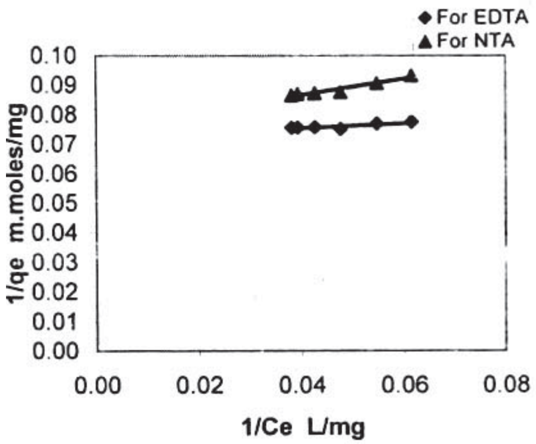

Fig. 4: Langmuir isotherm

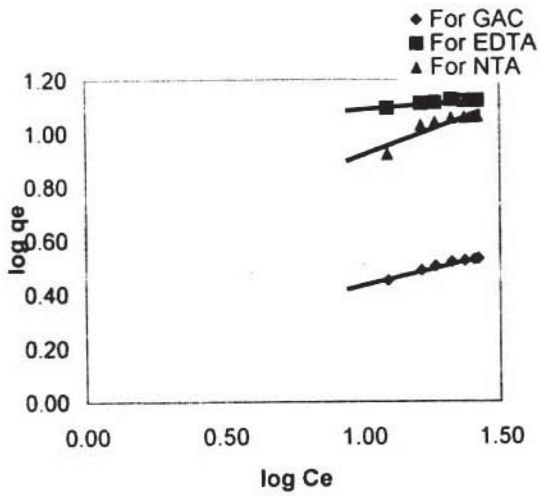

Fig. 5: Freundlich isotherm

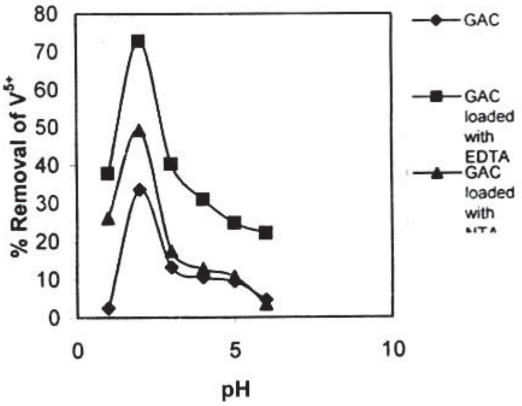

Fig. 6: Effect of pH on % removal of V5+

Plot of log qe Vs log Ce was also found to be linear. The values of B and k are presented in Table 1. Since the values of B are less than 1, it indicates favourable adsorption.

Effect of pH on the Removal of Vanadium (V)

The effect of pH on the removal of Vanadium (V) is shown in figure 6. Experiment were conducted at the constant initial Vanadium (V) concentration, adsorbent dose (GAC) of 0.5 gml 100 mL and the contact time of 3 hours. Results indicate that GAC loaded with EDTA has the maximum adsorption capacity for removal of Vanadium as compared to GAC loaded with NTA and GAC used independently.

This establishes that the pH of the aqueous solution is an important controlling parameter in the adsorption process. It was observed that the percentage removal of Vanadium (V) is higher at pH-2 and then decreases with increase of pH.

CONCLUSIONS

1. Removal of Vanadium (V) by adsorption with G. A. C. loaded with ligand (EDTA or NTA) has more adsorptive power as compared to the use of G. A. C. alone.
2. The developed technique of retrieval of Vanadium ions using G. A. C. loaded with ligand appears to be a cheap and practically viable for the use of semiskilled workers in the village.
3. The present work on adsorption process is in good agreement with Langmuir isotherm indicating monolayer adsorption process.
4. The results on adsorption process reveals that at pH = 2.0, Vanadium uptake capacity is better.

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