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Removal of Chloride from Ground Water Using Natural Adsorbent: Water Hyacinth

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Abstract

Groundwater contaminants in rural areas often include chlorides and hardness. Nowadays, due to water scarcity, there is a need to utilize groundwater for construction purposes. According to IS 456:2000, the chloride content in water used for mixing and curing concrete must not exceed 2000 mg/l for plain concrete and 500 mg/l for reinforced concrete work. An excess amount of chloride in water causes the deterioration of structures. Concrete durability and strength can be compromised by hard water, characterized by elevated mineral levels. This study aims to devise an efficient treatment system capable of lowering chloride and hardness concentrations in groundwater to acceptable levels while minimizing treatment costs. The water hyacinth plant is used as a natural absorbent in this process. The adsorption capacity of water hyacinth is determined through studies, including parameters such as the initial concentration of influent, contact time of influent and absorbent layer, and flow rate of influent. This study shows that the chloride content of the water sample is reduced by 17%-20%, and the hardness is reduced by 20-25%.

Keywords: Water Hyacinth, Natural Absorbent, Chloride Ions, Hardness, Biodegradability

INTRODUCTION

Water suitable for drinking purposes is considered as most suitable for concrete construction for strength and durability. The municipal corporation treats the surface water and supplies it for domestic purposes to the society. Due to scarcity of water, the municipal corporation does not allow the use of treated water for construction purposes. Also the cost of treated water for commercial purposes is more than domestic purpose. Therefore, ground water obtained from open wells and bore wells is used for construction and curing purposes. Groundwater obtained from open wells and bore wells is the major source for drinking water and construction activities in rural areas. Generally ground water (Bore well water) contains hardness and chlorides. These impurities react with the concrete and affect the strength and durability. [T. Salih et al.,2011] [20]Various methods are used to treat the groundwater such as electrode ionization process [Wang L et al., 2009], [16] electro membrane processes [Park J.S et al, 2007],[13] capacitive deionization [Seo S.J at al., 2010], [17] ion exchange process [Apell I.N & Boyer T.H, 2010, Kazemian H. et al., 2003] [6,18] and adsorption [Torabian A. et al., 2010] [19] for the removal of hardness and chloride content. Various species from ground water are responsible for hardness (i.e Ca+2 and Mg+2 cations).Amongst the developed processes, adsorption is the one which is used to treat the water by using some naturally available materials such as fly ash [Mall I.D et al, 2006], [11] peanut [Gong R. et al,2005], [10] sawdust [Malik P.K, 2004], [7] pumice stone [Catalfamo P.,2006], [9] rice husk [Mane V.S. et al,2007], [14] banana and orange peel [Annadurai G.et al, 2002], [3] jackfruit [Inbaraj B.S., Sulochana N, 2002], [4] orange peel

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[Namasivayam C.et al,1996], [1] coir pith waste [Namasivayam C., Kavitha D.,2002], [5] sugar beet pulp [Aksu Z., Isoglu I.A.,2006], [12] neem leaf powder [Bhattacharyya K.G., Sharma A.,2005], [8] pumpkin seed [Hameed B., El-Khaiary M.I., 2008] [15] and guava leaf powder [Singh D., Srivastava B.,1999] [2] etc. The objective of the present study is to prepare an adsorbent layer from water hyacinth plant and compare the physical properties of Charred water hyacinth with activated charcoal. This study also helps to determine adsorption capacity of water hyacinth.

MATERIALS AND METHODS

Materials

Groundwater samples are collected from different rural areas. Groundwater samples have chloride concentration more than 400 mg/lit, hardness more than 500 mg/ lit, pH varies from 6.5-7.5 Alkalinity varies from 70-110 mg/lit.

Water Hyacinth

Water Hyacinth (E. crassipes) is a major fresh water weed generally available in the entire region and it affect the growth of some aquatic plant. Plant forms dense colonies that block sunlight which harms aquatic life. This plant is useful in water treatment also. Roots of Water Hyacinth plant helps to remove impurities present in water. Properties: High adsorption capacity, large surface area, Natural availability & cost effectiveness, Biodegradability, Regeneration potential, Nutrient removal capacity Figure 1.

Figure 1. Water hyacinth plant.

Fine aggregate: Aggregate of of size 1-2 mm is used for filtration layer. Aggregates should be angular in shape and non-porous in nature.

Coarse Aggregate: Aggregate of size 4-5 mm is used for filtration layer. Aggregates should be angular in shape and non-porous in nature.

METHODOLOGY

For this research groundwater and well water samples are collected from different areas near Nasik. Various tests like pH, Hardness, Alkalinity, chloride content are performed on collected samples and compared with standard permissible limits. Hardness and chloride content in groundwater samples are more as compared to standard limits. For removal of chloride and hardness, an absorption method is used. Water hyacinth plant is used for preparation of adsorbed layer as it has high adsorption capacity.

Preparation of Adsorbent Layer

Adsorbent layer is prepared in the form of charcoal. Preparation of the adsorbent layer is economically feasible as we use aquatic weed which is easily available in ponds and lakes.

Plants of Water Hyacinth are collected from nearby ponds or lakes or the banks of rivers. The plants are subsequently rinsed multiple times with fresh water to eliminate moss, mud, dirt, and other impurities. They are also washed with distilled water to remove tedious materials.

Acid Activation

About 25 grams of this material (material includes leaves and roots of Water Hyacinth Plant) is taken and treated with 20 ml of concentrated H_2SO_4. Following thorough mixing, the charred material is obtained and left overnight. After this period, the charred material undergoes heating in an oven at 100°C for approximately 4-6 hours. Subsequently, the material is cooled and meticulously washed with distilled water to eliminate any residual acid, achieving a pH range of 6 to 8, which is optimal for chloride determination using the argentometric method. Acid activation is employed to enhance the efficiency of chloride ion removal, resulting in a highly protonated surface on the adsorbent material. Table 1 This surface property facilitates the attraction of more chloride ions, leading to a heightened chloride adsorption rate in the acidic medium. This enhanced adsorption is attributed to the strong columbic forces between the positively charged surface and the negatively charged chloride ions Figure 2.

Figure 2. Charred Form of Water hyacinth

Physical property of charcoal and Water Hyacinth (Charred Form) is compared, we found similarity in results.

Table 1. Physical property of charcoal and Water Hyacinth.

S.N.	Physical Properties	Water Hyacinth (Charred Form)	Charcoal
1	Nature	Solid	Solid
2	Appearance	Black	Black
3	Odour	Pungent	odorless
4	Solubiliy	Insoluble in water	Insoluble in water
5	Porosity	High	High
6	Reaction with Water	Hydrophobicity	Hydrophobicity (insensitiveness to moisture)
7	Adsorption Capacity	High	High
8	Cost	Low	Low

Determination Of Chloride Ion

Method used: Mohr's method

Principle: The Mohr's method of estimation of chlorides concentration in water sample is based of two factors.

1. (a) The ability of silver ions to precipitate chlorides ions as AgCl
   (Ag^+ + Cl^- → AgCl) ↓
   white ppt.
   (b) The ability of silver ions precipitate chromate ions as silver chromate in neutral or a near alkaline medium (pH 7 to 8)
   ($2Ag^+$ + CrO_4^{--} → Ag_2CrO_4) ↓
   Reddish brown ppt.

2. When Ag^+, Cl^- and CrO_4^{--} ion are all present at the same time , Cl^- ions are precipitated – in preference to CrO4 = ions.

It is only when Cl^- ions are precipitated, that excess of Ag^+ ions (in the absence of Cl^- ions) react with CrO_4 = ions to form reddish brown ppt. Of Ag_2CrO_4, which is regarded as the end point. The amount of Ag^+ ions used is a measure of the chloride concentration in the sample.

Apparatus Required

1. Burette, 50 ml –1 No.
2. Pipettes, 25 ml – 1 No. and 5 ml-1 No.
3. Conical flask. 250 ml – 1 No.

Chemicals

1. Silver Nitrate (0.0141 N), titrant – (2.395 g $AgNO_3$ per litre)
   1 ml 0.0141 N $AgNO_3$ = 0.5 g Cl-
2. Potassium Chromate , indicator –
   (50 g K_2CrO_4 + A little distilled water, dissolve + A little 0.0141 N $AgNO_3$ to form a stable red ppt. Digest overnight, filter and dilute to one litre.)
3. Standard Sodium Chloride (0.0141 N)
   (824.1 mg dry NaCl per litre) 1 ml = 0.5 g Cl-.
4. pH papers, universal range.
5. 1 N H2SO4 and 1 N NaOH (for correcting pH).

Procedure

a. Standardization of AgNO3 (Titrant) -
   1. Take 10 ml of standard (0.0141 N) NaCl in a conical flask.
   2. Add 100 ml of distilled water.
   3. Check pH (it should be between 7 and 8 – correct. If necessary, using 1 N NaOH or 1 N H2SO4 as required).
   4. Add 1 ml of K2Cr O4 indicator.
   5. Titrate against AgNO3 Until a stable reddish brown ppt is just formed at the end point.
   6. Record the amount of titrant used = x ml.

b. Blank Correction:
   1. Take 100 ml of distilled water in a conical flask.
   2. Repeat steps 3 to 5 of (A).
      Record the amount of titrant used = y ml.

c. Sample Titration:-
   1. Take 10 ml of the sample in a conical flask.
   2. Repeat steps 2 to 5 of (A)
   3. Record the amount of titrant used = z ml

Calculations

1. Normality of Titrant (N)
   $(x - y) \times N = 10 \times 0.0141$, $N = 10 \times 0.0141/(x-y)$

$AgNO_3$ NaCl

2. Chloride concentration
   In the sample, mg / l = (z – y) ml × N (mg / ml) × 35.453 × 1000 (ml/l)
   Sample taken (10 ml)
   Sample taken
   Where: Z= ml of titrant used, y = ml titration for blank.

Adsorption Isotherm

Adsorption is usually described through isotherms, that is, the amount of adsorbate on the adsorbent as a function of its pressure (if gas) or concentration (if liquid) at constant temperature. The quantity adsorbed is nearly always normalized by the mass of the adsorbent to allow comparison of different materials. The Langmuir adsorption model is the most common model used to quantify the amount of adsorbate adsorbed on an adsorbent as a function of partial pressure or concentration at a given temperature. The first mathematical fit to an isotherm was published by Freundlich and Küster (1894) and is a purely empirical formula for gaseous adsorbate,

$$\frac{x}{m} \quad P^{\frac{1}{n}} k$$

Where, x is the quantity adsorbed, m is the mass of the adsorbent, P is the pressure of adsorbate and k and n are empirical constants for each adsorbent-adsorbate pair at a given temperature. The function has an asymptotic maximum as pressure increases without bound. As the temperature increases, the constants k and n change to reflect the empirical observation that the quantity adsorbed rises more slowly and higher pressures are required to saturate the surface.

Preparation of Model

Model Specifications:

a. Free board = 100 mm
b. Flow Rate = 2.84 LPM
c. Operating Pressure = 125 psi (8.6 bar)
d. Operating Temperature = 5-50°C

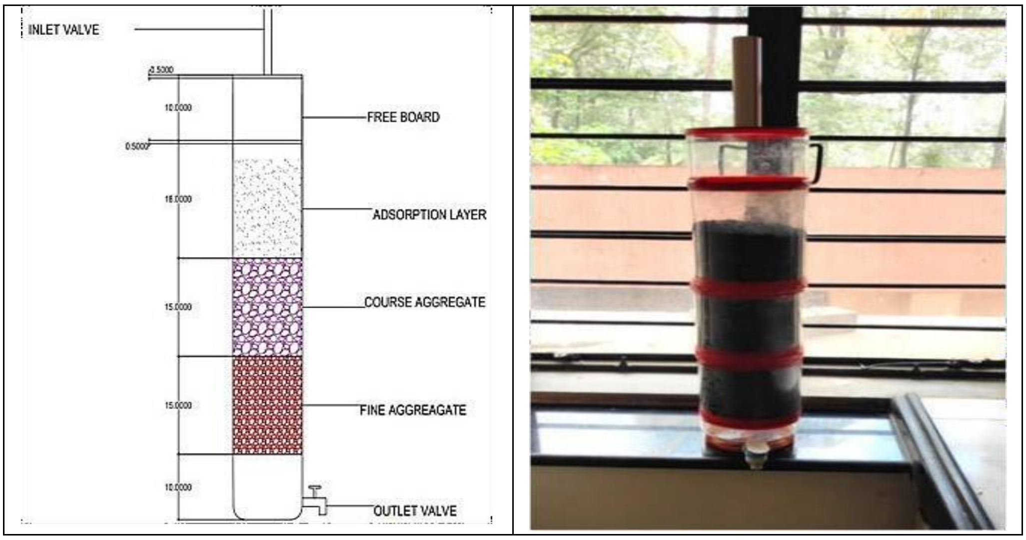

Figure 3. Shows a pilot scale model of diameter 130 mm having three layers of filtration bed.

As top provide a freeboard of 100 mm height for retention of water at inlet level. First layer is of water hyacinth in Charred Form which will act as adsorbent layers of height 150 mm. Second layer is of fine aggregate of size 1-2 mm and height 150 mm. Adsorbent layers and fine aggregate layer are separated by an iron mesh and strainer. Third layer is of coarse aggregate of size 4-5 mm and height 150 mm. Second and third layer will act as a filtration layer. Coarse aggregate and fine aggregate layer is separated with an iron mesh. At the bottom is to provide a freeboard of 100 mm for the outlet. Foam sheet is provided at top of adsorbent layer for uniform flow distribution of water over adsorbent Figure 3.

RESULT AND DISCUSSION

pH

This influent had a pH of 6.5-7.5 which is almost neutral. Treated wastewater having pH value is around 7-7.5. Considering that the water hyacinth adsorbent layer is suitable that the pH of influent and effluent water is not too acidic or alkaline.

Table 2. Water quality analysis.

S.N.	Parameter	Flow type	pH	Alk	Hardness	Cl
1	Chandori	Inf.	6.5	72	837	342.4
		Effl.	7.1	70	607	275.6
2	Sinnar	Inf.	6.9	128	585	130.4
		Effl.	7.5	120	434	106.4
3	Pimpalgaon	Inf.	6.6	104	828	114.1
		Effl.	7	101	642.5	94.6
4	Ozar	Inf.	6.5	102	510	133.3
		Effl.	7.2	98	382.5	109.2
5	Row sample	Inf.	6.5	105	620	900.5
		Effl.	7.5	98	465.5	737.4

Alkalinity

Alkalinity of effluent is reduced by 4-7%. Considering that a water hyacinth adsorbent layer is suitable helps to maintain the alkalinity of the water sample.

Hardness

The results show that the hardness of the water is reduced by 22-26% after passing the water through filter media. This shows that the water hyacinth adsorbent layer is suitable for removal of hardness from hard water samples.

Chloride

The results show that the chloride content of the water is reduced by 18-20% after passing the water through filter media. This shows that the water hyacinth adsorbent layer is suitable for removal of chloride from water samples Table 2.

CONCLUSION

The Chloride content and Hardness of bore water is more as compared to well water and tap water. After testing of effluent (i.e. passing through filter model) chloride content of water sample reduced by 18-20 %, Hardness by 22-26%, Alkalinity by 4-7%. It is proven to be cost effective method for treating hard water.

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