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Flouride Removal from Ground Water Using Natural Adsorbents

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Abstract- Fluoride contain in water is a major health issue for human beings, Generally in India where undeveloped area and developed area also people consume excess amount of fluoride in drinking water and that's the reason cause risks such as dental and skeletal fluorosis. There are many technologies and methods to fluoride removal such as coagulation-precipitation, membrane separation, ion exchange, and adsorption processes. Yet, because of the high installation and maintenance expenses of membrane and ion exchange operations, adsorption has become an affordable and effective alternative. We have focused to make low-cost filtration candle with using natural adsorbents which are locally available in market.

This research concentrates on the removing of fluoride from water through the use of natural adsorbents, which are cost-effective, environmentally friendly, and readily available. The research investigates the performance of various natural materials, including activated carbon, rice-husk, cement adsorbents, in removing fluoride contain. The adsorbent method is commonly used in nations such as India because of its simplicity and effectiveness.

By a comprehensive literature review and experimental investigation, this research assesses the adsorption capacity, removal efficiency, and viability of these natural adsorbents. Findings show that natural adsorbents have great potential for large-scale fluoride removal and can be a good solution for safe drinking water supply in fluoride-endemic areas. Nevertheless, more studies are required to optimize adsorption parameters and determine their long-term use on a commercial scale.

This research is part of the increasing literature on sustainable water treatment technologies, with a focus on the importance of low-cost, effective, and scalable defluoridation methods to provide access to safe drinking water in fluoride-affected regions.

Keywords: Natural adsorbents, Cement, adsorption, defluoridation.

1. INTRODUCTION

Fluoride because of its profound impact on human welfare has attracted global attention. Intake of the high dose of fluoride over the long term lead to different symptoms of health ranging from dental fluorosis (yellow and chipped teeth), skeletal fluorosis (deformed and rigid bones) and other non-skeletal manifestations, from gastric to reproductive systems. The poor and underdeveloped countries such as Africa and Asia have the largest population affected by fluorosis. In addition, millions of individuals in these nations are exposed to fluoride-rich water because of the lack of infrastructure and resources leading to morbidity and sufferings. As fluorosis is widespread in nearly all regions of the globe and, over time, there has been minimal success in treating the health impacts and prevention of exposure to this toxic substance is still the only possible method. Hence, there is a compelling necessity to seek a solution to minimize fluoride contamination of groundwater. There are numerous sources of fluoride exposure to humans; however, groundwater has been the leading route of exposure owing to the widespread and reliance of individuals on groundwater, particularly in the rural sector Owing to the excessive content of fluoride in groundwater, public health worldwide is under threat. Because the primary pathway of fluoride exposure is through the drinking water, therefore to regulate adverse health impacts of fluoride regulating fluoride in the drinking water is required. Apart from groundwater, fluoride is also added by numerous industrial processes which emit a high volume of wastewater that must be treated prior to releasing it into streams and rivers.

Fluoride Remediation by Adsorption

Adsorption is regarded as one of the most effective fluoride removal technologies from drinking water when compared to other fluoride removal technologies in terms of initial cost, design flexibility and simplicity, ease of operation, and maintenance. The effectiveness of this method greatly relies on adsorbents (Stoica Ligia et al 2012)[2] Adsorption is a function of ions (adsorbent) in liquids diffusing into the surface of a solid (adsorbent), where they form bonds on the solid surface or are bound there by feeble inter molecular forces. [2].

Adsorption is a function of ions (adsorbent) in a liquid diffusing to the surface of a solid (adsorbent) where they combine with the surface of the solid or are trapped there by weak inter molecular forces. Adsorption of fluoride onto solid absorbent typically goes through three stages.

1. External mass transfer is the diffusion or movement of fluoride ions from bulk solution via the boundary layer around the adsorbent particle to the outside of the adsorbent;
2. Fluoride ion adsorption on particle surfaces;
3. The adsorbed fluoride ions likely exchange with the structural components within adsorbent particles based on solid chemistry, or the adsorbed fluoride ions are passed to internal surfaces for porous materials [3].

A number of adsorbent materials have already been experimented with to determine an effective and cost-effective defluoridation agent. Some of those adsorbents include activated coconut shell carbon and activated fly ash, groundnut shell, coffee husk, Phyllanthus emblica, bark of babool, pine apple peel powder, orange peel powder, grind neem and pipal leaves, groundnut shells, etc. Adsorption techniques are employed for fluoride removal and these techniques are applied when fluoride is available in low concentration (Sharma Sharad et al 2014) [3].

- **Advantage of low-cost adsorbents over conventional adsorbents.**

Removal efficiencies of fluoride ions by different non conventional adsorbents vary from 50 to 90% based on the properties and adsorbent particle size. A blend of adsorbents can be employed equally well in defluorination treatment. Non conventional adsorbents are cheaper than conventional ones and available easily due to the cost savings. Non conventional adsorbents need simple alkali or/and acid treatment for the removal of lignin prior to their use and for enhancing efficiency. As these adsorbents are relatively inexpensive, they can be utilized once and then discarded. Non conventional adsorbents need less maintenance and monitoring. Separation can be done to separate the non conventional adsorbents from the effluents prior to their disposal. These unconventional adsorbents can be disposed of safely and conveniently. Reused adsorbents can be reused as a filling material in low-lying grounds and thus their disposal does not create any significant problem. (Jamode et al.2004) [5]

Effects of Fluoride

The high concentration of fluoride in the portable water badly influence the well-being of the water consumers and lead to fluorosis which occurs in three forms such as:

Dental fluorosis:

Dental fluorosis causes discoloring, mottling and blackening of the teeth. Children below the age of 8 years are more susceptible to the dental fluorosis problems. If the fluoride level falls below 0.7 mg/l and the continuous exposure to such conditions is not prevented, then cavities begin to develop in the teeth along with several tooth deformities (WHO, 2004) [6]

Skeletal fluorosis:

Skeletal fluorosis is the stage of bone deformities in which bones of the humans are deformed permanently along with pain in the muscles and other joints. Fluoride is a calcium loving element. When it reaches in the body through the water, then it affected to the bones and cause bone weak (Jamode et al, 2004). [7]

Non-skeletal fluorosis:

It causes the gastro problems along with neurological disorders. It also affects the I.Q. of the children.

The mental growth of the children is retarded and increase in the nervousness, thirst etc. is noticed after fluorosis is detected in the human body. It commonly affects the joints of the body and certain stomach and liver problems (Wondwossen, 2004). [8]

Global scenario

The international defluoridation scenario is an urgent concern for millions, mainly in developing nations in Asia and Africa. Fluoride levels in groundwater are high in many locations, High fluoride concentrations in groundwater, often exceeding the WHO recommended limit of 1.5 mg/L, lead to fluorosis, a debilitating condition causing dental and skeletal problems. While various defluoridation techniques like adsorption, precipitation, ion exchange, and membrane processes exist, many are costly or unsustainable for affected regions. Electrolytic defluoridation and locally sourced adsorbents offer promising, cost-effective solutions. Addressing this challenge requires continued research, technological advancements, and community-level interventions to ensure access to safe drinking water for vulnerable populations.[10]

Indian scenario

The defluoridation situation in India is serious because fluoride contamination of groundwater is prevalent across 22 states, impacting millions of people. The permissible fluoride level in drinking water is 1 ppm, but concentrations often exceed this, leading to dental and skeletal fluorosis. Various defluoridation techniques are employed, including the Nalgonda technique (using aluminum salts, lime, and bleaching powder), adsorption using activated alumina or herbal materials, ion exchange, and membrane processes like reverse osmosis. The need for cost-effective and community-based solutions is paramount, with ongoing research focusing on enhancing indigenous materials for fluoride removal. The Indian government, through initiatives like the Jal Jeevan Mission, is working to provide safe drinking water to affected populations.[11]

Deflouridation methods

Defluoridation techniques are methods used to remove excess fluoride from drinking water. High levels of fluoride in drinking water can lead to dental and skeletal fluorosis, which are serious health conditions. The choice of the most appropriate defluoridation technique depends on various factors, including the initial fluoride concentration, water quality, available resources, and the scale of treatment required. [12]

Here are some common defluoridation mehods**:**

1. Adsorption
2. Precipitation/coagulation
3. Ion exchange
4. Membrane processes

Adsorption

Adsorption is a widely used and effective method for defluoridation, the process of removing excess fluoride from water. It involves passing contaminated water through a material called an **adsorbent**, which attracts and retains fluoride ions on its surface.[13]

Here's a detailed breakdown of the adsorption materials for defluoridation:

- **Composition materials**

1. Cement

Cement is a binding material and it is form in fine powdered form. which is help to binding material together. Cement paste particles with sizes less than 0.15 mm were used as cement pastes for candle making. Cement paste, cured mixture of cement and water, was investigated for fluoride removal as abundant and cheaper alternative agent and ettringite for fluoride removal by precipitating CaF_2 and/or adsorbing F^- ions. The objectives of this study are to assess the feasibility of using cement paste as an alternative agent for fluoride removal and to investigate fluoride removal capacity of cement paste.[14]

2. Coarse aggregate

Granular materials are known as coarse aggregates. It is frequently used to make concrete in construction.

Crushed stone, gravel, or recycled concrete make up the majority of its composition.Coarse aggregates typically amounts for more than 60-80% of the volume of the concrete. The strength and workability of the concrete are greatly impacted by the coarse aggregate's quality, which also determines how long they last. Coarse aggregate passing 10mm retained on 6mm IS Sieve. coarse aggregate, like gravel, acts as a supporting layer and a pre-filter, trapping larger particles and ensuring even water flow, preventing clogging of finer filter materials and prolonging the lifespan of the candle. Coarse aggregate , often gravel, form the base layer of a filter candle , providing a stable and porous foundation for the Coarse aggregate, often gravel, forms the base layer of a filter candle, providing a stable and porous foundation for the finer filter media (like sand or activated carbon). The gravel layer acts as a pre-filter, capturing larger particles, sediment, and debris that would otherwise clog the finer filter materials. The porous nature of the gravel allows for even water flow through the filter candle, preventing or bypassing of the water, which can reduce filtration efficiency. By removing larger particles, the gravel layer protects the finer filter media from clogging and premature degradation, extending the lifespan of the filter candle. By removing the larger particles, the gravel layer allows the finer filter media to work more effectively, leading to improved water quality

.Rice husk

Rice husk is the outer cover of a rice grain. Rice husk is a by-product of rice milling and is commonly discarded, but it has a number of applications because of its physical and chemical characteristics. It has a porous structure, which allows it to effectively filter out impurities from water. The high surface area of rice husk enables it to adsorb (attract and hold) impurities, making it an effective filter medium. It is a natural, biodegradable, and non- toxic material, making it an environmentally friendly option for water filtration. Rice husk can be used to remove suspended solids, such as particulate matter, bacteria, and viruses, from water. It can also be used to remove organic pollutants, such as pesticides and industrial chemicals, from water. Benefits of rice husk is a low-cost material, making it an affordable option for water filtration.

3. Coal

Coal is a fossil fuel that is mostly made up of carbon, with other elements like hydrogen, sulphur, oxygen, and nitrogen. It is created from plant and other organic matter remains that were buried and exposed to heat and pressure for millions of years. It is a non-renewable energy source and has been used as a significant energy source for centuries. Coal has a porous structure and high surface area, making it an effective adsorbent for removing fluoride ions from water. Its natural and biodegradable composition also makes it an environmentally friendly option. Fluoride ions are adsorbed onto the surface of coal through weak Waals forces or electrostatic forces, with maximum removal efficiency at acidic pH. Fluoride ions bind to functional groups on the coal surface, forming chemical bonds. Positively charged coal surfaces attract negatively charged fluoride ions, enhancing adsorption.

4. Activated carbon

In comparison with activated carbon, biochar is a superior adsorbent material with the merits of low cost, abundant sources, and strong affinity for heavy metal removal from contaminated aqueous solutions. Activated carbon has a highly porous structure and large surface area, making it an effective adsorbent for removing fluoride ions from water. Its high adsorption capacity and ability to remove a wide range of contaminants make it a popular choice for water treatment. Activated carbon has shown excellent results in removing fluoride from water, with adsorption capacities ranging from 10 to 100 mg/g. Activated carbon has a high adsorption capacity for fluoride ions. Investigating optimal operating conditions, such as pH and temperature, for fluoride removal. - Comparing activated carbon's performance with other adsorbents, such as zeolites and ion exchange resins.

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