

Review on Effects of Fluoride Contamination and Remediation Methods

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Abstract—Surface water resources in Rajasthan are not abundant so people are dependent on ground water for their needs. One of the main sources of fluoride ingestion is water. If the fluoride ion concentration (CF) in drinking water is less than 1.5 mg/L, fluoride is good for your health (WHO 1994). It is important to voice concerns on the alarmingly high fluoride levels in groundwater. The health of people is negatively impacted by these contaminants' increased amounts. Too much fluoride poses major risks to one's health since it affects the teeth and bones. Three types of fluorosis are present in the disease: non-skeletal, skeletal, and dental. Dental fluorosis can result in pitting and leaves teeth with diffuse dark stains. The backbone and joints become extremely painful and rigid due to skeletal fluorosis. Various techniques are employed for the removal of fluoride from ground water in the paper but the upmost requirement is to make people aware to minimize those practices that make the water more contaminated of these pollutants.

Keywords— Pollutants, fluoride, Dental, Skeletal, Non-Skeletal, health.

I. INTRODUCTION

Water is the most essential element on Earth among all the systems that are required for life support. Animal life, as well as flora and fauna, cannot thrive without water. The ocean covers more than 70% of the surface of the planet. However, only one percent of that water is easily used by humans, and of that one percent, ninety-nine percent is held underground as ground water. The majority of the requirements for drinking, irrigation, washing, and other activities that are required of plants and animals are met by ground water. Rivers and lakes are refilled in part by groundwater. Regrettably, pollutants can easily enter groundwater. Some of the factors that contribute to ground water being dangerous and unsuitable for use are mining operations, as well as man-made items like chemicals, oil, and gasoline. The state with the worst water deficit is Rajasthan [1]. There aren't many surface water resources there. The majority of the water needed, especially for drinking, comes from groundwater alone. However,

a high percentage of fluoride has contaminated ground water in the majority of the state's districts. The gradual natural breakdown of fluorine stored in rocks releases fluoride into subsurface water sources. Fluoride is often found in minerals and geological deposits. For humans, fluorine is essential because it promotes healthy development and keeps tooth enamel from eroding in acidic environments. According to a research released by the Union Drinking Water and Sanitation Ministry, the highest concentration of habitations with groundwater containing fluoride is found in the state of Rajasthan. The rocky belt that runs through Rajasthan from Delhi to Gujarat might be the reason behind the high level of fluoride in the water in the state. There are also mica mines in the vicinity, and the groundwater there is fluoride-rich. Fluorides are absorbed from the gastrointestinal system and dispersed throughout the body depending on the components of the diet. Seafood and drinking water are excellent sources of fluoride [2].

II. SOURCES AND HEALTH HAZARDS

When fluoride was first used to prevent dental cavities in the 1940s, there was debate over its effectiveness on two fronts. Fluoride inhibits the enzymes that make oral bacteria that produce acid, which erodes tooth enamel. This observation is true, however some experts now think that fluoride has considerably more detrimental effects on other helpful enzymes than it does on preventing dental cavities. When dental enamel grows in youngsters, fluoride ions strengthen it by their binding with calcium ions. Many academics now consider this more of an assumption than a fact due to conflicting results from research carried out in India and numerous other nations over the past ten to fifteen years. All concur, however, that taking too much fluoride depletes the tooth matrix of calcium, aggravating rather than preventing the development of cavities throughout life and leading to dental fluorosis. An irreparably crippling disorder known

as skeletal fluorosis can arise from severe, continuous, and cumulative overexposure[3].

The primary mineral present in teeth (particularly enamel) and bones, hydroxyapatite, $\text{Ca}_5(\text{PO}_4)_3\text{OH}$, has hydroxide ions that are replaced when fluoride intake is excessive, resulting in the more durable compound hydroxyapatite, $\text{Ca}_5(\text{PO}_4)_3\text{F}$. This provides some partial enamel reinforcement. Long-term exposure to fluoro apatite causes dentures and bones to become brittle and hardened[4].

People who consume excessive amounts of fluoridated water over time might get fluorosis, a chronic condition. A different term for fluorosis in teeth is "mottled enamel" [5]. Teeth become discolored and acquire horizontal yellow streaks as a result. When adults and children have fluoride levels above 3 mg/l, they develop skeletal fluorosis in addition to tooth fluorosis. One of the most prevalent symptoms of skeletal fluorosis is back and joint pain. In severe cases, this could render the patient completely incapacitated. Fluoride overuse can also result in non-skeletal health issues such as anemia, renal damage, inactivation of reproductive organs, allergies, gastrointestinal issues, urinary tract issues, and degeneration of the nerves and muscles.

Since skeletal and dental fluorosis are the two main conditions brought on by consuming tainted groundwater containing fluoride, they have been thoroughly discussed [6].

SYMPTOMS OF FLUOROSIS

Dental fluorosis: When teeth are forming, often between the ages of 0 and 6 or 8 years, excessive use of fluoride-contaminated drinking water can lead to dental fluorosis in humans. Tooth enamel hypoplasia, or hypomineralization, is another name for dental fluorosis, which is associated with an abundance of F^- assimilation into these structures. Throughout the calcification or tooth formation stage, teeth are more vulnerable to fluorosis, especially in the first seven years of life. Crystalline calcium phosphate, often known as hydroxyapatite, accounts for over 87% of the substance that constitutes tooth enamel. Fluoroapatite is formed when the increased intake of F^- from drinking water displaces the hydroxide ions (OH^-) from the oxidation of hydroxyapatite. Dental fluorosis starts

here, but if F^- -contaminated water is consumed over time, teeth will become brittle and hard.. In the enamel, there is also mottling, staining (from yellow to brown to black), and pit development. Spots or horizontal streaks may be the appearance of discoloration. Generally speaking, tooth discoloration. turns into a crucial component of the tooth matrix, which causes the teeth to lose their luster. Dental fluorosis can be categorized as mild, moderate, severe, fairly mild, or normal based on the amount of fluoride consumed and the degree of water pollution. As mentioned before, in mild cases of dental fluorosis, the tooth surface may show opaque regions of chalky white discolorations or white horizontal striations. Advanced forms of dental fluorosis might eventually cause the opaque areas to become yellow, brown, or even black. Furthermore, there is a chance that the teeth's increased porosity will result in structural issues like pitting or breaking. It is not always the case that an adult without dental fluorosis is getting the required quantity of fluoride, as these effects become apparent if the teeth were fully formed prior to the fluoride overexposure [7, 8].

Skeletal fluorosis: Increased bone mass and density, as well as skeletal and joint symptoms including pain, deformities, and calcification in the joints, are the hallmarks of skeletal fluorosis, which is brought on by excessive fluoride consumption. The first symptoms might be intermittent stiffness and soreness in the joints; other possible warning indications are headaches, stomachaches, and weakening in the muscles. At initially, there may be a number of mild symptoms of skeletal fluorosis, such as joint pain, stiffness in the joints and bones, muscle weakness, sporadic soreness, and chronic fatigue. Bone calcification takes place during the intermediate stage of fluorosis, and is followed by stiffness or hardening of the joint. Severe joint stiffness, intermittent discomfort, and skeletal fluorosis throughout the first and second clinical periods [9]. Osteosclerosis, or the hardening and calcification of the bones, is the following stage, and at this point the nervous system, muscles, spine, and main joints are all affected. A condition known as "poker back" occurs when skeletal fluorosis is severe enough to cause the bones to stiffen steadily until the spine as a whole consists of one fixed column of bone. Last but not least, the commencement of the third clinical phase (crippling skeletal fluorosis) is characterized by neurological

impairments, abrupt calcification of ligaments, skeletal bone abnormalities, and restricted joint mobility [10].

Fluorosis, whether it be skeletal or dental, cannot be reversed and has no known cure. The sole treatment is to avoid problems in the first place by consuming fluoride in moderation.

III. REMEDIAL METHODS

The World Health Organization states that the most amount of fluoride that can be present in drinking water is 1.5 mg/l. Setting national fluoride regulations, however, should also take into account other aspects such as food, water intake, and climate. There are two ways to regulate the amount of fluoride in groundwater. The first step is to look for nearby alternate water sources with low or acceptable fluoride concentrations. Using other water sources, such as surface water, precipitation, and low F⁻ groundwater, is one way to prevent the negative consequences of consuming F⁻ polluted water. Because surface water is naturally contaminated by both biological and chemical agents, it is typically not feasible to consume it without first treating and disinfecting it. Moreover, developing nations may find surface water treatment to be too costly and intricate. Rainwater is a low-cost, straightforward alternative that can offer a cleaner supply of water than surface water. There are situations where utilizing rainwater presents challenges, such as the unequal distribution of rainfall and the capacity of rainwater storage in homes or communities. The concentration of F⁻ in groundwater can vary over time in both vertical and horizontal directions due to its uneven distribution [11,12].

Defluoridation is an effective and applicable method to reduce the concentration of F⁻ in drinking water when alternate water sources are not available. Either central water treatment at the source or point-of-use water treatment, or household level, can be used to accomplish this. In less developed states like Rajasthan, the first option is defluoridation done on a massive scale under the supervision of qualified individuals [13]. It is not practical due to its high cost. The second technique, treating water at the point of use, is more economical because defluoridation is carried out based on the amount of water needed for drinking and cooking, which is

often less than 25% of the total amount needed. The water that needs to be treated to remove fluoride only needs to have various chemicals added to it [14]. For instance, in the Nalgonda approach, the water is treated by first adding lime (5% of alum), then optional bleaching powder, and last alum (Al₂(SO₄)₃.18H₂O) [15]. This is followed by coagulation, sedimentation, and filtering. Calcium and phosphate compounds are added to water to remove fluoride using the contact precipitation method of de-fluoridation. Fluoride precipitation occurs due to the catalytic action of CaF₂ and/or fluorapatite in the presence of a saturated bone charcoal media. An other viable technique for de-fluoridation is the adsorption/ion-exchange process [15,16]. This process involves passing raw water over a bed of de-fluoridating material or an adsorbent that, through ion exchange, chemical reaction, or physical means, retains fluoride [17].

Other practical techniques for removing F⁻ from water include ion-exchange, electrocoagulation, reverse osmosis, precipitation/coagulation, nanofiltration, adsorption, and adsorption processes [18]. Alum seems to be the most often utilized component, even though a number of compounds may effectively remove F⁻ during the precipitation/coagulation process. Furthermore, compared to the traditional precipitation/coagulation process, electrocoagulation produces a lot less waste sludge [19]. Compared to RO, nanofiltration requires less pressure, which lowers energy expenditures. Nevertheless, the cost of nanofiltration membranes is higher than that of RO membranes [20, 21].

IV. CONCLUSION

Fluoride enrichment in groundwater is often attributed to the emergence of Fluoride bearing minerals in deep rocks and their interaction with water. Groundwater with fluoride poses a risk to human society. The unsustainable use of groundwater resources by growing population is the main contributing agent of increasing fluoride contamination. It is wise to investigate the activities that are contributing to the toxins' excessive levels of water contamination. Once groundwater contamination happens, it can be challenging to clean up [22]. Many people in Rajasthan who are impoverished are not aware of the fluoride health concerns associated with drinking water. However, local regulatory organizations are not concentrating

on cleanup even though they are aware of the health dangers associated with this. Large-scale fluoride treatment is expensive, thus communities and local governments should concentrate on community-based treatment methods. The local population should be informed and educated to help in the provision of appropriate and affordable remedial technologies. Also it is important to use ground water carefully so as not to damage its natural qualities. It is important to raise people's awareness of the issues surrounding water contamination, particularly in rural areas. Government organizations should educate the public on affordable, manageable, and environmentally friendly remediation techniques.

REFERENCES

- [1] Tressaud, A. (2019). Fluorinated compounds in our environment: Fluorine, friend or foe for humanity? *Fluorine*, 151-239.
- [2] Hussain, I., Arif, M., & Hussain, J. (2011). Fluoride contamination in drinking water in rural habitations of central Rajasthan, India. *Environmental Monitoring and Assessment*, 184(8), 5151-5158.
- [3] Yadav, A., Kumari, N., Kumar, R., Kumar, M., & Yadav, S. (2023). Fluoride distribution, contamination, toxicological effects and remedial measures: A review. *Sustainable Water Resources management*, 9(5).
- [4] Arlappa N, Aatif Qureshi I, Srinivas R. Fluorosis in India: An overview. *Int J Res Dev Health* 2013;1:97-102.
- [5] Dean HT. Classification of mottled enamel diagnosis. *J Am Dent Assoc* (1922) 1934;21:1421-6.
- [6] Jayaprakash K. *A Short Textbook of Preventive and Community Dentistry*. New Delhi: Jaypee Brothers Medical Publishers Pvt Ltd;2004.
- [7] Gopalakrishnan P, Vasana RS, Sarma PS, Nair KS, Thankappan KR. Prevalence of dental fluorosis and associated risk factors in Alappuzha district, Kerala. *Natl Med J India* 1999;12:99-103.
- [8] Susheela AK. Dental fluorosis. In: Susheela AK, editor. *A Treatise on Fluorosis*. 2nd ed. Delhi: Fluorosis Research and Rural Development Foundation; 2003. p. 54.
- [9] Dahiya S, Kaur A, Jain N. Prevalence of fluorosis among school children in rural area, district Bhiwani: A case study. *Indian J Environ Health* 2000;42:192-5.
- [10] Srivastava AK, Singh A, Yadav AS, Mathur A. Endemic dental and skeletal fluorosis: Effects of high ground water fluoride in some North Indian Villages. *Int J Oral Maxillofac Pathol* 2011;2:7-12.
- [11] Singh M, Saini A, Saimbi CS, Bajpai AK. Prevalence of dental diseases in 5- to 14-year-old school children in rural areas of the Barabanki district, Uttar Pradesh, India. *Indian J Dent Res* 2011;22: 396-9.
- [12] Arif M, Husain I, Hussain J, Kumar S. Assessment of fluoride level in groundwater and prevalence of dental fluorosis in Didwana block of Nagaur district, Central Rajasthan, India. *Int J Occup Environ Med* 2013;4:178-84.
- [13] Kumar, A., Chava, R., Gupta, S., Shirin, S., Jamal, A., & Yadav, A. K. (2023) Environmental and health effects of fluoride contamination and treatment of wastewater using various technologies. *Advanced Treatment Technologies for Fluoride Removal in Water*, 323-341.
- [14] Divyadeepika, Yadav, K., & Joshi, J. (2023). Fluoride pollution control techniques and principles. *Advanced Treatment Technologies for Fluoride Removal in Water*, 43-69.
- [15] Rao, P., Suneetha, N., Rupa, K., Sabitha, V., Kumar, K., Mohanty, S., & Kanagasabapathy, A. (2008). Defluoridation of water by a one step modification of the Nalgonda technique. *Annals of Tropical Medicine and Public Health*, 1(2), 56
- [16] Kumar, D., & Kumar, K. (2023). Fluoride removal from water using adsorption method with different compounds: A comprehensive review. *Journal for Research in Applied Sciences and Biotechnology*, 2(5), 132-138
- [17] Kimambo, V., Bhattacharya, P., Mtalo, F., Mtamba, J., & Ahmad, A. (2019). Fluoride occurrence in groundwater systems at global scale and status of defluoridation – State of the art. *Groundwater for Sustainable Development*, 9, 100223.
- [18] Mumtaz, N., Pandey, G., Labhasetwar, P.K., 2015. Global fluoride occurrence, available technologies for fluoride removal and electrolytic defluoridation: a review. *Crit. Rev. Environ. Sci. Technol.* 45, 2357–2389.
- [19] Emamjomeh, M. M., & Sivakumar, M. (2009). Fluoride removal by a continuous flow

- electrocoagulation reactor. *Journal of Environmental Management*, 90(2), 1204-1212.
- [20] Cai, Y., Yang, X. J., & Schäfer, A. I. (2020). Removal of naturally occurring strontium by Nanofiltration/Reverse osmosis from groundwater. *Membranes*, 10(11), 321.
- [21] Shen, J., Schäfer, A., 2014. Removal of fluoride and uranium by nanofiltration and reverse osmosis: a review. *Chemosphere* 117, 679–691.
- [22] Guidelines for drinking-water quality incorporating the first and second addenda (4th ed.). (2022). World Health Organization.