Preface

Water, revered as "a primary source of all that exists" by ancient philosophers, continues to be one of the most enigmatic and vital substances on Earth. Its exceptional properties and the essential role it plays in sustaining life highlight the importance of ensuring its purity and availability. However, the contamination of water resources, particularly groundwater, with harmful substances like fluoride and nitrate, poses a significant threat to public health globally. Ground water serves as the source of drinking water for a large population in India. High concentrations of metals and other toxicants such as arsenic, fluoride, and nitrate have been found beyond threshold limit in ground water of many parts of India making it unfit for drinking purpose. A significant proportion of groundwater suffers from the twin problems of nitrate and fluoride contamination. Nitrate in groundwater comes from many sources such as nitrogen fertilizers, animal wastes, municipal wastes, landfills, septic tanks, soil organic matters and discharge of domestic and industrial wastewater. On the other hand, dissolution of minerals in the rocks and soils is major source of fluoride in water. The current maximum permissible limit of nitrate, prescribed by Bureau of Indian Standards (BIS) for drinking water in India is 45 mgNO_3/L. For fluoride, the desirable limit is 1.0 mg/L and permissible limit in absence of any alternate source of drinking water is 1.5 mg/L.

Fluoride and nitrate contamination of drinking water are widespread environmental problems that pose significant health risks to millions of people globally. Exposure to high levels of fluoride can cause dental fluorosis, a condition that weakens tooth enamel and leads to discoloration and pitting of the teeth. In severe cases, skeletal fluorosis can develop, leading to bone pain, stiffness, and joint deformities. Arthritis, cancer, infertility, brain damage, Alzheimer syndrome, and thyroid disorder have also been reported by intake of high concentration of fluoride intake. Excess concentration of nitrate in water can cause several problems such as methemoglobinemia and gastric cancer, abdominal pain, diarrhoea, vomiting, hypertension, increased infant mortality, central nervous systems defects, birth defects, diabetes, spontaneous abortions, respiratory tract infections and changes to the immune system, formation of N-Nitroso compounds which are carcinogenic. The development of effective and sustainable methods for removing fluoride and nitrate from drinking water is essential to safeguard public health and well-being.

Among the common techniques of nitrate removal, biological denitrification and ion exchange methods have been suggested by World Health Organization (WHO) while ion exchange, reverse osmosis and electrodialysis are approved by United States Environmental Protection Agency (USEPA) as Best Available Technologies (BAT). Similarly, common methods for fluoride removal from water are adsorption, ion-exchange, precipitation-coagulation, reverse osmosis, electrolytic defluoridation, electrodialysis etc. Most of these methods have high operational and maintenance cost. The generation of secondary pollutants, such as toxic sludge, and membrane fouling are significant associated problems in water treatment. Adsorption is generally considered a better treatment option due to its convenience, ease of operation, and simplicity of design. Hydrous metal oxides are among the most widely studied materials in drinking water treatment applications. Hydrated alumina, zirconium oxide, and nano-alumina have been reported to remove nitrate from water under suitable conditions. Similarly, materials such as activated alumina, manganese-oxide-coated alumina (MOCA), hydrous-manganese-oxide-coated alumina (HMOCA), Fe/Al mixed hydroxides, iron and aluminium-based mixed hydroxides, Mn–Ce oxide, aluminium hydroxides, Fe–Al–Ce hydroxide, and Fe–Al–Ce tri-metal hydroxide have been examined for fluoride removal from water.

With the objective to develop sustainable media for nitrate and fluoride removal from water, this study focuses on evaluating the potential of biochar-based adsorbents for their application in drinking water treatment. By creating biochar composites specifically designed to target fluoride and nitrate, this research aims to develop an efficient, cost-effective, and eco-friendly solution for water purification. Biochar, produced from organic biomass through pyrolysis, stands out as a sustainable and eco-friendly option for water treatment. Its production process not only utilizes waste biomass, thereby contributing to waste management and resource recycling, but also ensures a reduced environmental footprint. The high adsorption capacity of biochar is attributed to its porous structure and large surface area, which provide abundant active sites for the effective removal of contaminants such as fluoride and nitrate. This makes biochar an efficient solution for addressing water contamination issues. Additionally, biochar is cost-effective; its production is relatively low-cost compared to other adsorbents, making it economically viable for large-scale water treatment applications. Its versatility further enhances its appeal, as biochar can be engineered and modified to improve its adsorption properties by incorporating additional functional groups or combining it with other materials, thus tailoring its efficiency to target specific contaminants. Moreover, biochar exhibits high chemical stability and resistance to degradation, ensuring long-term performance in water treatment systems. Unlike some other adsorbents, biochar generates minimal secondary pollutants during the adsorption process, thereby reducing the environmental impact and contributing to a cleaner, safer water supply.