CHAPTER 5

Conclusion

ANNEXURE – I

(published research papers)

5.1. General Conclusion

Primarily, a novel green adsorbent named as CIHFO has been prepared by simple co-precipitation method in laboratory condition with an aim that it can be effectively pertinent as green adsorbent for removal of fluoride from contaminated groundwater. Characterisation of this material has been done with the help of some modern technical tools like XRD, OP, SEM-EDX, TEM, XRF, BET analysis, AFM, TG and DTA analysis to understand its non-structural behaviour and it was found that thermally stable CIHFO (473K) is microcrystalline and amorphous in nature with high surface area but poses irregular surface morphology. A series of batch experiments carried to investigate fluoride adsorption behavior of CIHFO in aqueous medium in optimized pH 6.8-7.2.The better adherence of the equilibrium data with the Freundlich isotherm suggests the surface heterogeneity of CIHFO with multilayer adsorption and D-R isotherm results and desorption results revealed that fluoride adsorption occurs through ion-exchange which ultimately converted to chemisorption. Surface reaction occurs according to the pseudo-first as well as PSO kinetics with boundary layer (film) diffusion process. Nature of the adsorption reaction is reasonably spontaneous but exothermic in nature. Very low Arrhenius energy of activation inclines to the high affinity of CIHFO for fluoride.

'Column operation' process packed with agglomerated CIHFO nanoparticles (size: 841-1410 μm) has been carried out to find out its applicability in bulk scale in natural field condition. Performances of CIHFO packed fixed-bed column in different operational condition revealed that work efficiency of fixed-bed column was involved directly in proportional relation with the increment of both bed height and initial fluoride concentration but inversely proportional with increasing rate of effluent flow rate. BDST model and performance indicator also recommended that the CIHFO packed fixed-bed column could be considered as an effective medium for fluoride removal for higher fixed-bed height, slower rate of effluent discharge and lower initial fluoride concentration. Importance analysis of the developed ANN suggests that the initial fluoride concentration was acted as the key variable for the CIHFO packed fixed bed column operation followed by bed height and flow rate variation. Overall, based on different modeling interpretations, an attempt has been made to design of "prototype" filter unit with an aim that it can be effectively utilise in domestic household for fluoride removal. It can be concluded in that way that the data presented in this experimental process can be further extrapolated for designing and establishing any efficient fluoride removal plan while treating the fluoride enriched groundwater.

Again surface modification of CIHFO with hydrophilic graphene precursor (GO) and β-CD moiety successfully achieved by in-situ wet chemical deposition method with an aim that modified adsorbents could be able to remove more fluoride in same optimized operating condition. Both said as prepared adsorbent named as GO-CIHFO and βC-CIHFO, again characterized and have shown irregular surface morphology consisting of microcrystals (GO-CIHFO ~2-3nm; βC-CIHFO ~6.022nm) and mesoporous in nature. Both GO-CIHFO and βC-CIHFO were thermally stable and adsorption reaction is reasonably spontaneous and endothermic in thermodynamic sense. The change of Entropy ($\Delta S°$) has been estimated to be lower than 80 kJ mol^{-1} in neutral pH, suggested adsorption process happened mostly by ion-exchange at neutral pH. A comparative study based on calculated E_{DR} value for all three adsorbents and results obtained from filed validation are summerised in table below to evaluate the adsorption efficacy of these three proposed adsorbents.

Table 5.1: Comparative study between Langmuir fluoride adsorption capacity, Calculated E_{DR} value range and Adsorbent Dose required for treatment of natural groundwater samples obtained from experimental results for all three proposed adsorbents.

Adsorbent	Langmuir fluoride adsorption capacity (mg F.g^{-1})	Calculated E_{DR} value range (kJ mol^{-1})	Adsorbent Dose required for treatment of natural groundwater samples (9.05 mg.L^{-1})
CIHFO	32.62	12.61 - 20.32	2.4 g.L^{-1}
GO-CIHFO	80.42	8.32-9.87	1.2 g.L^{-1}
βC-CIHFO	52.32	8.77-10.17	1.8 g.L^{-1}

5.2. Application Potentiality of the Present Proposed Adsorbents

The following recommendations for future areas of research are based on an extension of the research performed in this study:

- ⊕ Fabrication of prototype" filter units packed with CIHFO, GO-CIHFO and βC-CIHFO and installation of these units in household level in fluoride affected region, primarily in West Bengal.
- ⊕ Application of these three adsorbent for treatment of arsenic enriched groundwater also with different proportion of Fe(III) and Ce(IV) as required.
- ⊕ Applying the adsorbents for treatment of industrial wastewater also to explore their applicability range.

5.3. Insight on Future Applicability and Avenues for Scientific Challenges

- ℵ Designing of different methods of synthesis to incorporate magnetic properties of these proposed adsorbents to enhance the regeneration and reusability aspects of these adsorbents.
- ℵ Fluoride adsorbed material, developed as by product from this treatment procedure can be used for semiconducting material after proper chemical as well as thermal treatment.
- ℵ Merging of environmental geochemistry, environmental chemistry with material science along with analytical inorganic chemistry to produce more green environment friendly products to reduce pollution and hence to get better environment.