ABSTRACT

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Title: Fluoride decontamination of groundwater using exfoliated biochar based sorptive system: A cradle to grave approach through vermitechnology.

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Fluoride (F^-) contamination of underground water table poses substantial threats to human health worldwide including India. This study was designed to investigate the spread and intensity fluoride contamination in lesser explored parts of Jharkhand, India. The Baliapur block of Dhanbad district and Mica mining regions in Giridih district were selected for the study. The fluoride source, spread, intensity and dynamics in the aquifer were evaluated here. Groundwater samples collected from both regions were categorized into F^- safe and F^- unsafe groups based on WHO's permissible F^- limit (1.5 ppm). Significant differences in fluoride concentrations between groups were noted. On analysing physicochemical parameters alkaline pH, high Na^+ and HCO_3^- levels, and extended time of rock-water interaction were found to enhance F^- accumulation. Observations of aquifer chemistry showed silicate weathering and carbonate dissolution to be the primary geogenic sources of fluoride. Logistic regression (AUC: 95.6%) and self-organising maps generated predictive efficiency for F^- in unsampled locations. Health risk assessments indicated non-carcinogenic risks, especially for children and Sobol sensitivity assessment showed concentration of F^- ion and body weight had the highest impact in it. High values of water quality and irrigational indices in F^- rich samples, denied their suitability of use. The application of modelling, machine learning, geospatial analysis and classical chemistry together aided prudent monitoring of water quality in areas impacted by fluoride.

Next, the study addressed F^- removal using an exfoliated biochar (EB) prepared from acid exfoliated water hyacinth (*Pontederia crassipes*). Batch adsorption experiments, and response surface methodology were performed to identify the optimized parameters affecting the process of adsorption. It was found that for pH 6, 30°C, and 20ppm of initial fluoride concentration a 86.08% removal efficiency was noted for a 6.5 gm/ltr of biochar. Monolayer adsorption following Langmuir isotherm (R^2=0.995) and chemisorption demonstrated by pseudo-second order reactions (R^2=0.997) were reported. Brunauer-Emmet-Taylor analysis suggested successful exfoliation from increased pore volume and surface area. Field emission scanning electron microscopy coupled energy-dispersive X-ray spectroscopy FESEM-EDX confirmed F^- uptake in biochar pores. The surface functional groups responsible for adsorption were identified with FTIR. The generated F^--laden biochars were subjected to remediation using vermicomposting. Temporal studies of compost physico-chemical parameters, microbial activity and F^- fractions were monitored to ensure a safe by-product. This vermi-sanitised biochar was then tested in rice and tomato cultivation, for tracing any F^- bioaccumulation in edible parts of crops and monitoring agronomic parameters. Results supported this vermi-composted product as a viable option for agriculture while simultaneously mitigating the F^- contamination. Overall, a comprehensive study which includes identifying fluoride contamination, producing a sustainable low cost green biosorbent from the otherwise unwanted water hyacinth to combat it and vermi-remediating the spent biosorbent to a valuable agricultural compost, was successfully addressed in this research.

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