Groundwater fluoride contamination scenario in selected sites of West Bengal and remedial measurement

Synopsis submitted by

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Thesis synopsis:

Fluorine is an abundant trace element in natural environmental conditions and usually, it manifests as fluoride (F^-). The present study evaluates the multi-dimensional aspects of F^- contamination in groundwater, along with its exposure in cultivated crops and vegetables, followed by human health risk assessment due to F^- toxicity in West Bengal, India. According to the report of the Public Health Engineering Department (PHED), Govt. of West Bengal, 43 blocks in seven districts covering 2.26 lakh people are affected by F^- toxicity. Obtaining such information from the block level of West Bengal, the present study has given importance to the extensive monitoring of groundwater, food chain entry, source of contamination and human health concerns in F^- contaminated areas. Further, studies were conducted focusing on the distribution pattern of F^- in groundwater from six districts namely South 24 Parganas, West Medinipur, Jhargram, East Bardhaman, West Bardhaman, and Murshidabad of West Bengal. A total number of 3287 groundwater samples were collected for this purpose. The presence of F^- in groundwater was found >1.5 mg/l in 10%, 11%, 4%, and 14% of samples from South 24 Parganas, Jhargram, West Bardhaman, and Murshidabad district, respectively. This study has evaluated first time the magnitude of F^- concentration in groundwater from nine newly F^- exposed blocks in West Bengal (Baruipur, Sonarpur, Binpur II, Salanpur, Baraboni, Jamuriya, Pandabeswar, Kandi, and Khargram). At present, the total number of F^- exposed blocks are 65 from 10 districts of West Bengal. About 3% of groundwater samples from West Bardhaman district significantly represented the class V toxicity level where F^- concentration was found >10 mg/l. According to the depth-wise distribution, the maximum presence of F^- was found in the depth range of 24.4 - 30.5 m in the southeastern part (South 24 Parganas) of West Bengal. One of the important studies has been evaluated to classify the role of minerals and related hydro-geochemical processes mainly responsible for releasing high concentration of F^- in groundwater from South 24 Parganas district. The distribution of cation and anion in the fluoridated groundwater samples follows the order of $Na^+ > Ca^{2+} > Mg^{2+} > K^+ >$ Fe and $Cl^- > HCO_3^- > SO_4^{2-} > NO_3^- > CO_3^{2-} > F^-$, in Sonarpur block and $Na^+ > Ca^{2+} > Mg^{2+} >$ Fe $> K^+$ and $Cl^- > HCO_3^- > SO_4^{2-} > CO_3^{2-} > NO_3^- > F^-$, in Baruipur block respectively. Furthermore, the Piper diagram showed that all the groundwater samples have represented the Na-Cl type and cluster analysis represented a strong primary cluster formation between Na^+ and Cl^- ions. Moreover, the positive silicate weathering condition played a significant role behind low Ca^{2+} concentration in groundwater. Additionally, Gibbs plot showed that all the groundwater samples fall between the zone of evaporation dominance and rock dominance zone, which proves the ionic interaction process occurring between groundwater and host silicate mineral. Significantly, the saturation index (SI) suggests that the groundwater is oversaturated and can be precipitated in the form of dolomite, and calcite. Where, chloro alkaline (CA) I and CA II values represent that both Mg^{2+} and Ca^{2+} ions can be absorbed on the exchangeable sites of host mineral and instantaneously, release Na^{+} and K^{+} ions into the groundwater. The borehole sediments has been investigated to identify the responsible source of F^{-} mineral. Moreover, the maximum F^{-} concentrations were found as 767 mg/kg and 600 mg/kg in borehole sediment samples in the depth range from 3.05 m to 6.1 m and 9.14 m to 12.19 m, respectively. XRD spectra showed the intense pick of muscovite present in borehole sediment. SEM-EDX study further confirmed that the groundwater F^{-} contamination is mainly of geogenic origin and predominantly influenced by muscovite.

The consumption of F^{-} through drinking water is either beneficial or harmful to human health according to daily ingested doses. Fluoride contamination is not only limited to groundwater, but with time it has spread into the food chain. The agricultural soil and food crops from F^{-} contaminated regions of Bankura and Purulia districts have been evaluated and found average soil F^{-} concentrations were 114 ± 59 mg/kg and 126 ± 65 mg/kg from Bankura and Purulia, respectively. Maximum F^{-} concentrations translocated from soil to plant body part in leafy vegetables compared to cereals, pulses and non-leafy vegetables. Moreover, nonleafy vegetables contributed the highest exposure of F^{-} (approximately 55.5%) to estimated daily intake (EDI) cumulative among all the food crops. The lifetime non-cancerous health risk (HI_{LTNR}) of F^{-} with percentile doses from P5 to P95 (exploring the model of Monte Carlo simulation) in all the studied age groups (4-70 years) was found to be >1 and indicating that the inhabitants were more vulnerable for their total lifetime period of F^{-} exposure through consumption of food crops from Bankura and Purulia district.

Likewise, the non-cancerous health risk was found to be comparatively higher in the southwestern districts (Jhargram, West Bardhaman, and the western part of Murshidabad) than in the southeastern districts (East Bardhaman, West Medinipur, and South 24 Parganas) of West Bengal. Urine is the most reliable indicator of F^{-}; however, no correlation was found between urinary F^{-} and groundwater F^{-} in contaminated areas (Ward no.6, Rajpur Sonarpur Municipality, Sonarpur block and Dhapdhapi II gram-panchayat, Baruipur block, South 24 Parganas district) and control area (Madhyabar, Pingla, West Medinipur district). The assessment of non-cancerous health risk showed a trend of infants being the most vulnerable, followed by adults, children, and teenagers among the inhabitants of these six districts.

According to the probabilistic health risk at P95 dose (by Monte Carlo simulation method) for infants were significantly more vulnerable (>1) to F^- toxicity in contaminated areas. The sensitivity analysis study has justified that oral exposure was more vulnerable than dermal exposure in the studied population.

The groundwater F^- removal techenique was focused based on the investigation of the performance efficiencies of the mitigation measures made by two different materials as seashell and dolomite and their mixture (1:1). All the adsorbents have supported the Freundlich isotherm model and Pseudo 2nd order kinetic model. Seashell and dolomite mixture (1:1) contributed the maximum F^- removal percentage of 85.5% from F^- contaminated groundwater (20 mg/l groundwater from Birbhum district). After F^- removal, the generated sludge was managed by brick formation.

So, promoting awareness programs on F^- severity and proper healthy nutritional food are highly suggested for the threatened inhabitants to fight against the overwhelming calamity of F^-.