

GIS BASED GEOCHEMICAL MODELING OF FLUORIDE CONTAMINATED AQUIFERS AND EXPOSURE RISK ASSESSMENT

by

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Department of Civil Engineering

Submitted
in fulfillment of the requirements of the degree of Doctor of Philosophy
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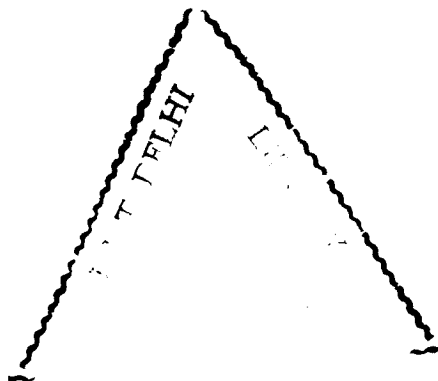
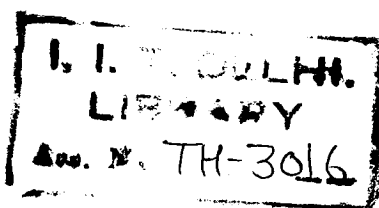


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CERTIFICATE

This is to certify that the thesis entitled “**GIS based Geochemical Modeling of Fluoride Contaminated Aquifers and Exposure Risk Assessment**” being submitted by Mr. **Sanjay Dharamraj Dhiman** to the **Indian Institute of Technology, Delhi** for the award of the degree of **Doctor of Philosophy** is a bonafide record of research work carried out by him under my supervision and guidance. The thesis work in my opinion, has reached the requisite standard, fulfilling the requirements for the said degree. The results contained in the thesis have not been submitted, in part or full, to any other University or Institute for the award of any degree or diploma.



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ABSTRACT

Fluoride contamination is becoming a serious concern in the Western India where the drinking water supply mainly depends on groundwater resources. An integrated approach combining mathematical contaminant transport model involving geochemical interactions, geographical information system (GIS), geostatistics and fuzzy logic is presented for better understanding of fluoride contaminated groundwater in the Mehsana district of Gujarat, falling under semi-arid regions of India.

Geochemical appraisal of fluoride contaminated groundwater is carried out to understand the prevailing geochemical processes in the study area. Global Positioning System (GPS) is used for groundwater and soil sampling. Physico-chemical analysis of groundwater samples and X-ray diffraction analysis of soil samples for mineral characterization is carried out. The hydrochemical data are analysed to develop a geochemical model for better understanding of prevailing geochemical processes and speciation modeling. A negative correlation is observed between fluoride and calcium a positive correlation between fluoride and bicarbonate alkalinity and sodium. A two factor model with 72% variance suggests that there is high factor loading for fluoride in sodium bicarbonate waters. Chemical trend analysis shows that dedolomitization and ion exchange are possibly the reactions occurring in the aquifer.

GIS embedded with geostatistical model is used to carry out autocorrelation and spatial variability analysis of geochemical species in the groundwater. The hypothesis of spatial dependence is tested and a monitoring network is designed using semivariogram modeling. GIS assisted groundwater flow model for transient state is calibrated and

validated using Processing MODFLOW, and flow paths / path lines are traced using PMPATH a particle tracking algorithm. GIS based geochemical modeling of the study area is carried out to investigate the plausible mineral phase transfers and to carry out sensitivity analysis for thermodynamic conditions and parametric effect. The thermodynamic conditions and parameters for the sensitivity analysis include partial carbon dioxide, temperature of percolation water and groundwater, mixing fraction, specific area of surface of hydrous ferric oxide, longitudinal dispersivity and cation exchange capacity. A USGS geochemical code PHREEQC is used for inverse and forward modeling. Mixing model and mixing with reaction transport model for a site is developed for simulating geochemical interactions of percolation water with groundwater. The simulated concentration values match fairly well with the observed chemical concentration values.

Results reveal that the groundwater is oversaturated with aragonite, calcite, dolomite, ferrihydrite, hematite and goethite, while undersaturated with anhydrite, carbon dioxide, gypsum, halite, fluorite, melantrite, siderite and jarosite-K. The dominant geochemical processes; dissolution of gypsum, dolomite, carbon dioxide and precipitation of calcite with exchange and surface complexation reactions, along with the physical processes; advection and hydrodynamic dispersion can adequately described the groundwater for quality dynamics for the study area.

A fuzzy logic and GIS based model is presented for the contaminant exposure assessment from the groundwater driven drinking water supply system. The uncertainties associated with the model are quantified using the fuzzy logic concept. The water consumption rate and the body weight of the users are considered as fuzzy imprecise

parameters, while the contaminant concentration as a crisp parameter. The convex, asymmetric and trapezoidal membership functions are developed for the infants, children and adults. Using fuzzy arithmetic and interval analysis, the fuzzy exposure dose for the infants, children and adults in spatial domain is calculated using thematic information derived from GIS analysis. Results reveal that the people including infants, children and adults in the study area of Mehsana district are exposed to high doses of fluoride from groundwater.

Models and results reported in this thesis will be useful in improving understanding of fluoride contaminated aquifers, evolving strategic management policies and remediation designs for aquifer restoration, planning health measures and alternate drinking water supply programs.

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