ASSESSING THE ROLE OF TRANSPORT MECHANISMS AND MODEL PARAMETERS ON CONTAMINANT PLUME DYNAMICS AND HEALTH RISK METRICS FOR THE SUBSURFACE ENVIRONMENT

Name - Abhay

Entry Id - 2018CEZ8388

ABSTRACT

Groundwater contamination is increasingly challenging and impacting the ecological environment and human health. To design remediation operations for contaminated regions, contaminant transport models that incorporate uncertainty associated with fate and transport mechanisms need to be developed. Health risk models are necessary to effectively transfer knowledge from technical to non-technical audiences. Moreover, health risk models should include the uncertainty associated with exposure model parameters, site- and activity-specific scenarios and exposure pathways for effective risk communication. This research delves into a multifaceted investigation of contaminant transport in the presence of low permeability porous media (LPPM) and dead-end regions and health risk assessment of the subsurface environment. A probabilistic human health risk assessment (HHRA) framework considering uncertainty in exposure model parameters such as body weight (BW), ingestion rate (IR), exposure frequency (EF), exposure duration (ED), skin surface area (SA) was developed to estimate non-carcinogenic hazard quotient (HQ) due to metal leaching from dumping sites (Okhla, Ghazipur, and Bhalswa landfill sites of Delhi, Ariyamangalam, and fly-ash dumping site Nasik) in India. Fly-ash dumping site in Nasik was found to pose the highest risk to human health in comparison to remaining considered dumping sites. An enormous difference between estimated HQ (child) and HQ (adult) for both the oral ingestion and skin dermal exposure scenarios was not observed. The variance attribution analysis indicated that the BW and ED contributed 35% to 55% towards the overall uncertainties of estimated HQs for children, and more than 95% of the contribution for adults was found to be governed by ED. An integrated ecological and HHRA framework was developed to assess the ecological and human health risks due to chromite ore processing residue (COPR) dumpsites in Kanpur, India. The multiple exposure scenarios (oral ingestion and skin dermal contact) and multiple pathways (soil and groundwater pathways) along the activity-specific scenarios were considered in the risk assessment framework. The teen playing in mud activity was found in the highest risk zone among all exposure scenarios in all population groups. The average value of HQ was found to be 4.5,

which is four orders higher than the safe limit, and the 95th percentile value of cancer risk (CR) was found to be 9×10^{-4} for skin dermal contact exposure scenario via soil pathway. The presence of Cr(VI) and U in groundwater near the Rania site, above the safe limit, was found to pose a significant threat to every population group. The maximum value of CR was found to be 54.9, the highest among all population groups.

A novel Teaching Learning-based Optimization (TLBO) and mobile-immobile (MIM) model-based integrated approach was implemented to simulate the solute transport through heterogeneous short- (30 cm) and long-column (12.5 m) conditions. The MIM model was found to capture the early arrival of solute, peak concentration, and long tailing in the breakthrough curve (BTC) well for conservative solute transport in 12.5 m long highly heterogeneous soil column and reactive solute transport in a 30 cm column-filled with Glendale clay loam soil. Further, the uncertainty associated with the flow and transport parameters of multispecies contaminants was quantified using Global Sensitivity Analysis (GSA). GSA of contaminant transport model based on temporal moment-based output indices indicated the complex interplay between different model parameters and their varying influences on different output indices. This research discussed the contrasting plume evolution dynamics observed in porous systems with and without LPPM regions from two-dimensional (2-D) numerical simulations. The contaminant mass recovery and mean residence time were found to be 25% to 50% lower and 25% to 40% higher in the porous system with the LPPM region than in the porous system without it, respectively.

In the end, contaminant transport model-driven probabilistic HHRA was conducted for a chemical mixture of Tetrachloroethene (also known as PCE) and its transformation products. The transformed daughter species i.e., Vinyl Chloride (VC), and cis-Dichloroethene (cis-DCE) were found to pose the highest risk to human health for a longer duration (up to 15 years) than the parent contaminant species i.e., PCE. The BW, concentration, ED, and IR were found to be major contributors to the total variance in the estimated risk metrics. Overall, the probabilistic risk assessment approaches, and numerical methods to analyze contaminant plume dynamics introduced in this thesis can be helpful in understanding the complexities involved in fate and contaminant transport and for policymakers to transfer knowledge from technical to non-technical audiences effectively.