Predicting Groundwater Contamination Risks in Parts of South Asia for Present and Climate Change Scenarios by Numerical and Artificial Intelligence Methods

Abstract

Extensive groundwater use is now inevitable for agricultural, industrial and domestic purposes worldwide, including countries like India, where more than 80% of drinking water supplies are met with groundwater. However, occurrences of contaminants in elevated concentrations from the point or non-point geogenic and anthropogenic sources render the groundwater resources unsafe for use. Thus, the present work attempts to delineate the distribution of groundwater geogenic (arsenic, fluoride and salinity) and anthropogenic (nitrate and coliforms) contaminants in India, including identification of the controlling factors. Numerical methods and artificial intelligence techniques were used for analyses of the present work. Furthermore, the present work also investigated the impact of climate change on groundwater quality (nitrate), for future years of 2030 and 2040.

The predicted probabilities of elevated arsenic occurrence ≥10 μg/L were observed for about 13% of the areal extent of India, with major occurrences in the Indus-Ganges-Brahmaputra river basins. Probabilities of groundwater fluoride above 1.5 mg/L were observed for about 23% of India, and the dry arid/semi-arid parts constituted the majority of the high-probability areas. About 29% of India was predicted with excess salinity, including coastal and inland areas. Geologic factors (like geotectonics and lithology) and groundwater occurrence depth were found to significantly influence all of the three geogenic contaminants, while climate factors were also found to be important for elevated fluoride and salinity occurrence.

For anthropogenic nitrate contamination of groundwater, the temporal changes between 2010 and 2017 were assessed, and the results showed a slight decrease in nitrate concentrations over the period in the study area. The spatial prediction indicated groundwater nitrate to exceed 45 mg/L in 37% of India. Anthropogenic factors (like N-fertilizer usage and population density) and climate factors were observed to significantly influence groundwater nitrate.

About 250 million, 257 million and 330 million people were estimated to be exposed to elevated arsenic, fluoride and salinity in groundwater, respectively, while about 447 million were to excess groundwater nitrate in India.

The agrarian state of Punjab, India, has been considered to investigate the impact of climate change on groundwater nitrate contamination. The predicted scenarios indicated that areas with high probabilities of nitrate contamination could increase to 49% and 50%

in 2030 and 66% and 65% in 2040 under two representative concentration pathways (RCPs), 4.5 and 8.5, respectively. However, the high-probability areas can decrease significantly by 2040 with restricted fertilizer usage.

For assessing groundwater coliform (total coliform and *E. coli*) contamination, field study, including groundwater and river water sampling were conducted in the Nadia district, West Bengal, India. Coliform contamination was strongly correlated with onsite sanitation facilities and also influenced by precipitation, depth to groundwater, population density, and surface water-groundwater interactions. The health risk analysis estimated the entire district to be at risk of diarrheal disease from pathogenic *E. coli*-contaminated groundwater ingestion. The present work can be an effective framework for identifying the extent of groundwater contamination in other areas globally and also assist in developing effective groundwater contamination management strategies.

Keywords: *Groundwater Contamination, Arsenic, Fluoride, Salinity, Nitrate, Coliforms, Artificial Intelligence, Spatial Prediction, Climate Change, Population Exposure, Health Risk*