EXECUTIVE SUMMARY

Assessment of groundwater vulnerability is crucial for sustainable water resource management in alluvial regions. This abstract provides a concise summary of a comprehensive study conducted to assess groundwater vulnerability in the alluvial region situated within the inter-basin of the Mahi and Narmada rivers (can be termed as Mahi-Narmada inter basin) flowing through Gujarat, India. Objectives are to identify different groundwater contamination sources, and develop appropriate groundwater vulnerability model, considering them. Validated vulnerability model parameters have been correlated with groundwater quality parameters to identify dominating contaminant. Subsequently, suitable methods are suggested to mitigate its concentration in groundwater, thereby minimizing risks to public health.

To identify potential sources of groundwater contamination, an extensive investigation of the study area was conducted considering various anthropogenic factors such as industrial effluent disposals, agricultural practices and urbanization. Multivariate statistical analysis was employed to identify and map sources of contamination. Utilizing techniques such as Principal Component Analysis (PCA), Factorial Spatial Analysis (FSA) and Hierarchical Cluster Analysis (HCA), this approach provided a comprehensive understanding of how anthropogenic activities affect groundwater quality.

A DRASTIC model Depth to water, Recharge, Aquifer media, Soil media, Topography, Impact of vadose zone, and Conductivity was developed by Aller Linda in the year 1987 to evaluate groundwater vulnerability. In this study, DRASTIC model is modified by including additional parameters, including layers of industries, sewage treatment plants and rural sanitation, were incorporated to enhance the model's accuracy. Weights were assigned to the model's parameters using ANN and a vulnerability index was calculated to identify areas at higher risk of groundwater contamination in an Arc-GIS environment. The assessment integrated hydrogeological and geospatial informations. Hydrogeological data provided insights into aquifer characteristics, while geospatial information helped to understand soil characteristics in the study area. The new parameters, FS and EI, introduced in the modified DRASTIC model, were validated using Pearson Co-efficient with Nitrate concentrations in groundwater for three successive years (2018, 2019 and 2020) during pre and post-monsoon period. Groundwater quality correlations were then analysed to establish the relationship between vulnerability and groundwater quality parameters using

Spearman's Rho method of correlation. The results showed significant correlations of vulnerability parameters with Groundwater Quality Index (GWQI), NO_3, TDS, TH and Ca. It was noticed that, areas with higher vulnerability index values were primarily associated with intensive agricultural activities, industrial zones, and densely populated urban areas, indicating that higher vulnerability corresponded to poorer water quality. This suggests the need for effective management strategies to safeguard public health.

Findings from the groundwater vulnerability assessment provide valuable insights for sustainable water resource management. Integrating contaminant source identification with a modified DRASTIC model and hydrogeological investigations allows for a comprehensive understanding of groundwater vulnerability and its relationship with water quality. Due to anthropogenic activities, Nitrate concentration in groundwater is continuously increasing, causing serious health concerns for infants and elders. Identifying "critical areas" for urgent remediation is imperative. According to the USEPA's proposed Health Risk Assessment, children face a greater health risk. The novelty of this study is the inclusion of hydrogeological parameters such as land-use maps, water use scenarios and population distribution in addition to the conventional HRA.

The study also suggests a suitable denitrification method based on the Analytical Hierarchy Process (AHP) of Multi-Criteria Decision Analysis (MCDA). The AHP method is used to recommend Nitrate reduction methods for each well identified (through sampling and testing) as having high-risk based on Nitrate concentrations above 45 mg/l. The study considered five leading Nitrate reduction methods: phytoremediation, pump and treat, pump and fertilizer, permeable reactive barrier and chemical reduction. These methods were evaluated using eight criteria: initial cost (IC), operation and maintenance cost (OMC), reduction time (RT), removal rate (RR), groundwater table (GWT), aquifer material (AM), location-specific characteristics (LSC) and contaminant loading (CL). The most suitable method for the Northern critical area is chemical reduction since the region is mostly covered in sandy soil and has a groundwater table between 30 to 50 feet. PAF is recommended for the Western critical area, which is close to the Mahi Estuary and contains clay loam soil. Suburban settlements in the central critical zone, with groundwater levels between 15 to 70 feet, require remediation using a permeable reactive barrier and a pump and treat method. These findings can guide policy makers, water resource managers, and local communities in making informed decisions to protect and manage groundwater resources effectively.