Assessment of Groundwater Salinity Using Hydrogeochemical and Multivariate Approaches in Ban Thum Area, Mueang Khon Kaen, Northeast Thailand.

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Northeast Thailand faces widespread soil and groundwater salinity issues, which adversely affect agricultural productivity, water quality, and ecosystem health. Moreover, increasing urbanization, industrialization, and agricultural expansion have heightened the demand for groundwater resources and amplified the risk of extensive groundwater and soil salinity problems in Ban Thum subdistrict, Mueang Khon Kaen district.

Objectives

This study aims to analyze the hydrogeochemical processes in shallow groundwater within a salinity-affected area using both graphical and multivariate statistical methods.

Study area

The study area is located in the southern part of Ban Thum subdistrict, Mueang Khon Kaen district, Khon Kaen province. The surficial layer of the study area consists of Quaternary unconsolidated materials. The Quaternary sediments overlie rock salt of the Maha Sarakham formation. Shallow groundwater is found within the unconsolidated aquifer, which can be classified as either unconfined or semi-confined aquifer.

Methods

Twenty groundwater samples were collected from the study area in January 2023. In-field measurements were conducted in to determine the hydraulic heads and assess certain properties of water samples, which comprised pH, electrical conductivity, and temperature.

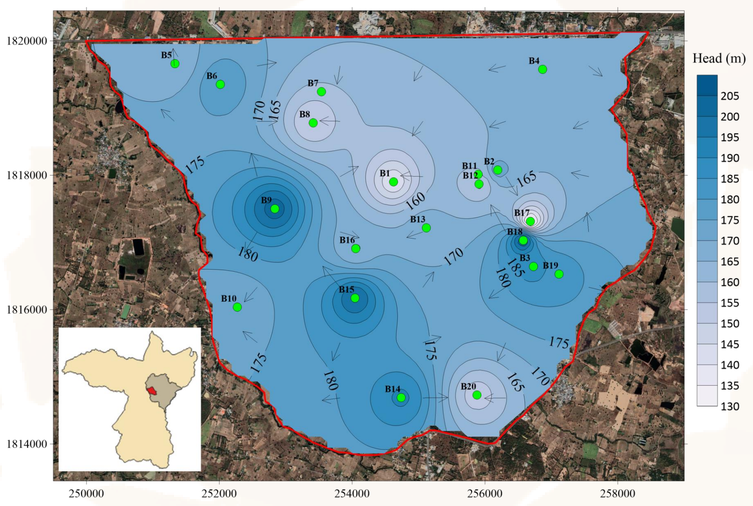
In the laboratory, the TDS, Major anions, including Cl^-, CO_3^{2-}, and HCO_3^-, Ca^{2+}, Mg^{2+}, K^+, and Na^+, and trace metals, including Cd^{2+}, Cu^{2+}, Fe^{2+}, Mn^{2+}, Pb^{2+}, and Zn^{2+}, were determined. The accuracy of the chemical analyses for the cation-anion balance was verified using the ion balance equation, ensuring that discrepancies were below 5%, which is acceptable.

The hydrogeochemical processes within the study area were identified using methods that included the Piper diagram, Durov diagram, hierarchical cluster analysis (HCA), principal component analysis (PCA). These methods provide a comprehensive understanding of the hydrogeochemical dynamics in this area.

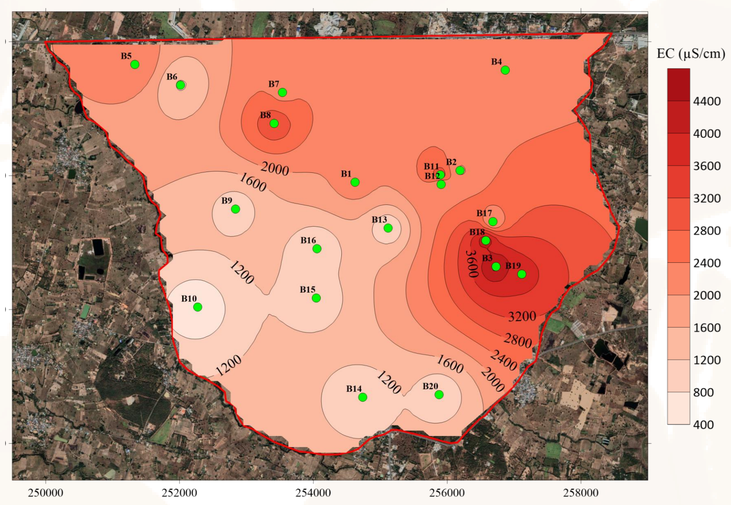
Results and Discussion

Hydrogeological Characteristics

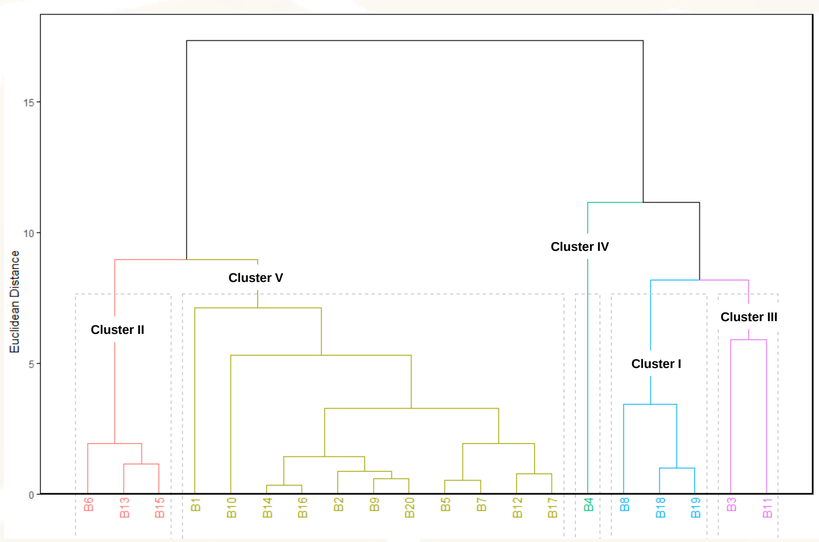
The primary direction of groundwater flow is from the northeastern part to the southwestern part of the study area. However, it exhibits several cones of depressions in the central region, and there is a high hydraulic head area in the southern part. This leads to the groundwater flowing from the south to the central part of the study area. The areas with lower hydraulic heads are associated with communities that have a high rate of groundwater extraction.



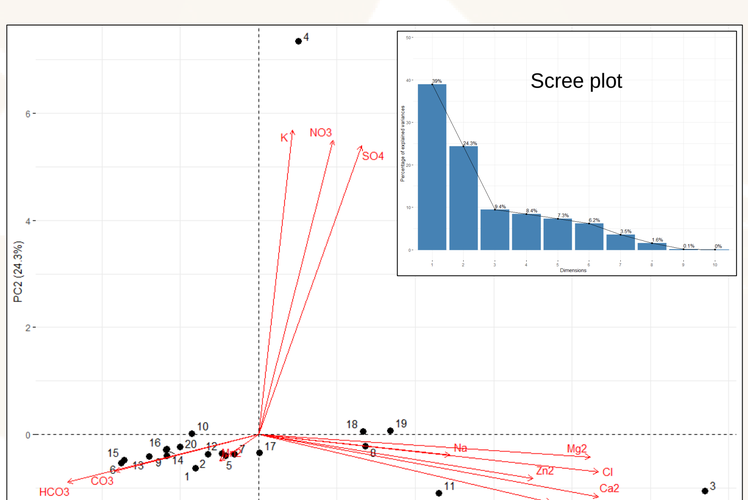
Groundwater contour map and groundwater flow directions of the study area



Spatial distribution of electrical conductivity



Dendrogram of hierarchical cluster analysis



Biplot shows both individuals and variables on the same plot, giving insight into the relationship between them.

Multivariate Statistical Analysis

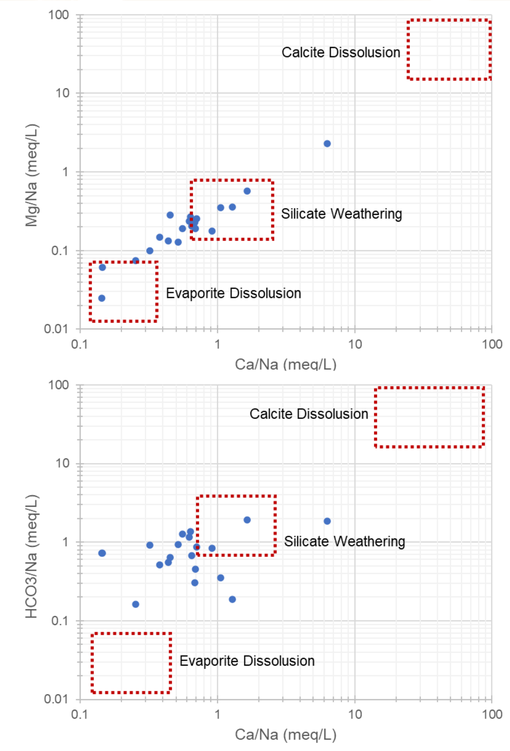
The results of the HCA analysis are visually represented in a dendrogram, which can be classified into five clusters:

- Cluster I: Groundwater samples in this cluster have high concentrations of sodium and chloride ions.
- Cluster II: This cluster shows lower TDS than Cluster I but has higher concentrations of carbonate and bicarbonate ions.
- Cluster III: Groundwater samples in this cluster have high pH, along with elevated levels of calcium and magnesium ions. These are also the only two samples where zinc ions were found.
- Cluster IV: This cluster exhibits low values across most variables.
- Cluster V: This cluster contains only one sample, which has high concentrations of sulfate and nitrate, indicating possible contamination from agricultural runoff or sewage.

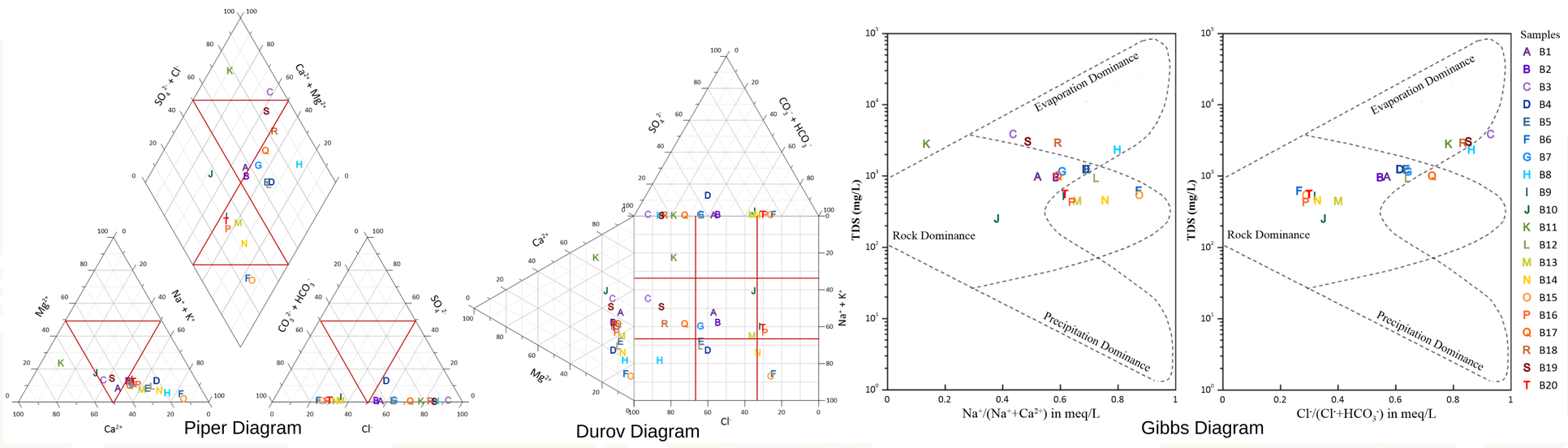
The scree plot from the PCA analysis shows that two principal components explain the majority of the variance. PC1 accounts for the highest percentage of variance, indicating the presence of several significant ions. PC2 also explains a notable portion of the variance and highlights ions that suggest contamination in sample B4.

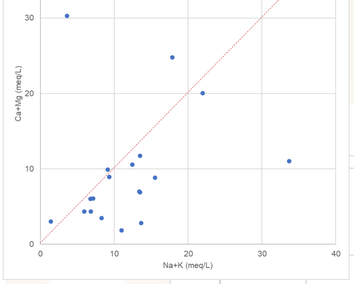
Hydrochemical Facies and Processes

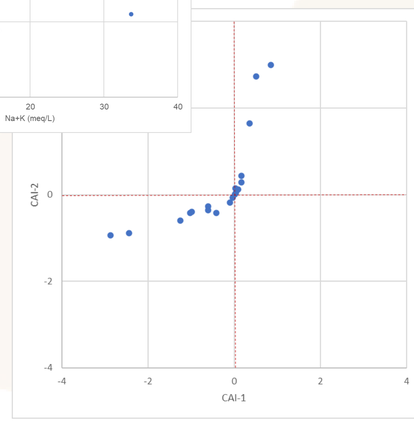
Groundwater falls within all zones of the Piper trilinear diagram. Diagram shows a trend of increasing Na^+ and Cl^- concentrations from the recharge area to the discharge area, which is a result of the halite dissolution process. The Durov diagram shows dissolution or mixing in the groundwater. Some samples are also located in the sodium and chloride-dominant field, indicating a possible ion exchange Na^+ and Cl^- in the water. Additionally, most samples are situated in the central part of the Gibbs diagrams, suggesting that rock weathering is the primary factor influencing groundwater evolution.



Furthermore, there is clear evidence of interactions between fresh and saline groundwater, resulting in high sodium-chloride and total dissolved solids content in the groundwater samples. Binary plot analysis of Ca^{2+}/Na^+ versus $HCO_3^-/Na+$ and Ca^{2+}/Na^+ versus Mg^{2+}/Na^+ suggests that most groundwater samples are plotted near the zone of silicate weathering, while samples with high salinity are plotted in the zone of evaporite dissolution. Likewise, the chloro-alkaline indices and binary plot analysis. of $Ca^{2+} + Mg^{2+}$ versus Na^+ indicate ion exchange and dissolution processes between the groundwater and aquifer materials.







Conclusion

This study offers a comprehensive understanding of the chemical properties of groundwater in the example salinity area in Northeast Thailand. Moreover, it provides a basis for resolving salinity problems, identifying the extent of salinity sources, enhancing groundwater utilization, and designing protective measures, all of which will contribute to ensuring the long-term sustainability of this essential resource.