Impact Assessment of landfills on Soil and Groundwater Quality in the Southeast of Rabigh city, Kingdom of Saudi Arabia

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Abstract

The landfill influences on the groundwater quality and the soil properties of the coastal city of Rabigh city, Saudi Arabia, were examined in terms of physical and chemical analyses. A total number of 31 samples (14 from groundwater samples and 17 soil samples) were collected to assess the involvement of the heavy metal ions within the vicinity of the study area. The outcomes showed persist groundwater contaminations with Na+, Ca2+, Mg2+, Cl-, SO42-. The majority of the chemical cationic contaminations were recorded in order as Na+, Ca2+, and Mg2+ respectively. While the anionic contaminations were recorded in order as SO42-, Cl-, HCO3-, and NO3- respectively. The spatial distribution of TDS exposes that the groundwater quality closes to the landfill sites is heavily impacted. According to Gibbs's analysis, the groundwater quality is controlled dominantly by the evaporation factor of the designated study area. Two hydrogeochemical type facies were identified, (NaCl and CaCl). The concentrations of the heavy metals in the groundwater samples were compared to the standard permissible limits of the General Authority for Meteorology and Environmental Protection (GAMEP), and soil samples were compared to the standard permissible limits of the Canadian Council of Ministers of the Environment (CCME). The findings of the current research discovered that the As, Cu, Zn, Mn, Al, and Fe metals were below the permissible limits. The soil's pH ranged from 7 to 9.6 with of 8.7 average pH value suggesting that the soils were strongly alkaline. The high alkalinity of the soils could be related to the occurrence of Sodium Carbonate or Sodium Bicarbonate. The spatial distribution of soil pH reveals that the highest value is located far from landfills, in the upstream part. The uppermost concentration of Chromium and Nickel elements in the soil exceeds the permitted threshold limit, while the uppermost concentrations of As, Cu, Zn, and Mn were below the permitted threshold limit.

Objectives

Rabigh city, characterized by intensive industrial activities and rapidly growing in terms of population and infrastructure. This rapid development results in a rising in waste generation. Thus, this study aims at assessing the environmental impacts of landfills on the soil and groundwater quality in the south-east of Rabigh city using geostatistical means.

Methodology

Geostatistics is a technique for characterizing the regular element of variation in natural phenomena, involving soils. In soil sciences, the implementation of the geostatistical methods provide quantifiable explanations of the spatial disparity of soils and enhances estimation accuracies of the soil characterization for data interpolation according to the spatial distribution equation [28]:

$$\gamma_{(k)}=\frac{1}{2n(k)}\sum_{i=1}^{n(k)}[Z(X_i)-Z(X_{i+k})]^2 \qquad \text{Eq. 1}$$

Where: n(k) - number of pairs of observation; Z(xi) - soil property measured in point x, and in point x + k.

The kriging method assumes spatial correlation which maintains that the distance and direction between sample points were the main factors dominating the projected values at unidentified points. Interpolation equation was conducted following Stoer and Bulirsch, [29]:

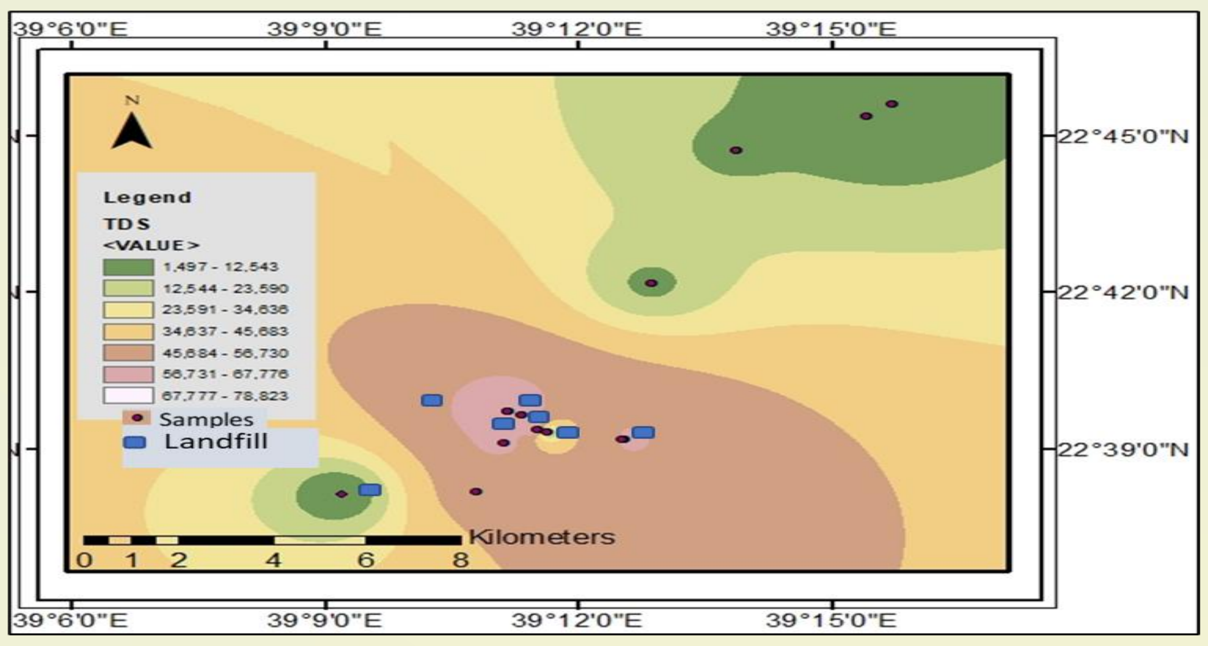
$$Zx(Xo)=\sum_{i=1}^{n}\lambda_i Z(x_i) \qquad \text{Eq. 2}$$

Where: Z x (xo) - interpolated value of variable Z at location Xo, Z(xi) - values calculated at location xi, λi; - weighed coefficients determined based on the semivariogram.

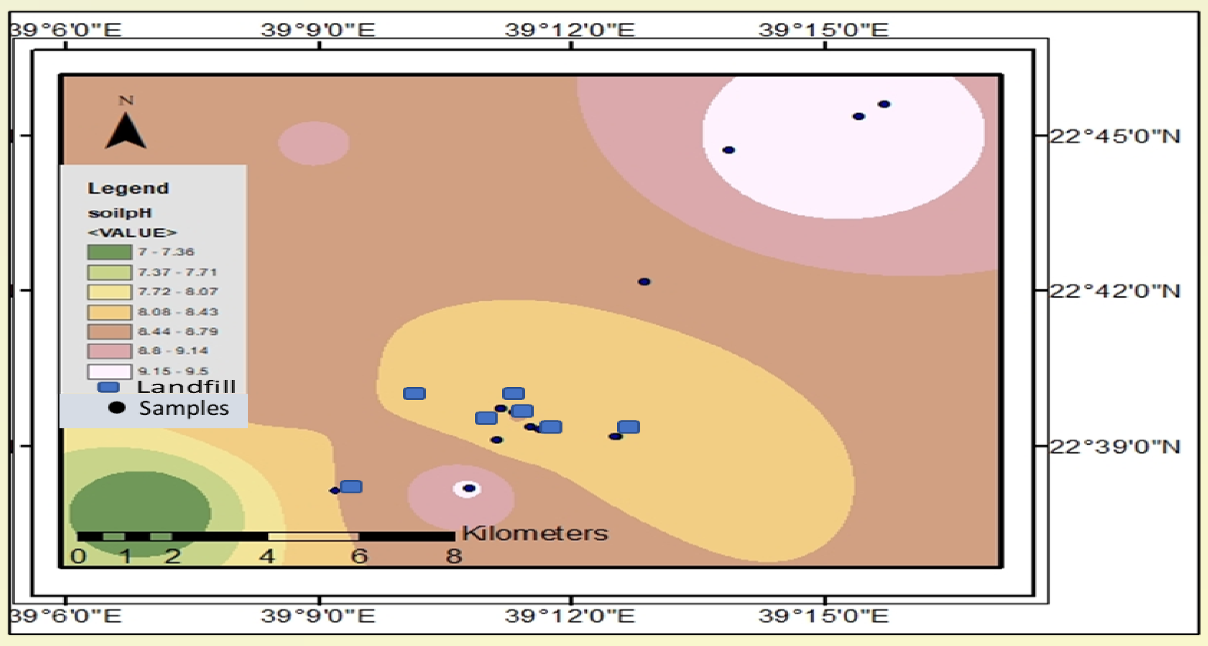
Since the weights were based on the distance and direction of the sampled data, the spatial arrangement must be in some way quantified. This quantification was done through the sample fitted model [29]. The trend and random error equation were conducted as follows:

$$Z(S)=\mu(S)+\varepsilon(S) \qquad \text{Eq. 3}$$

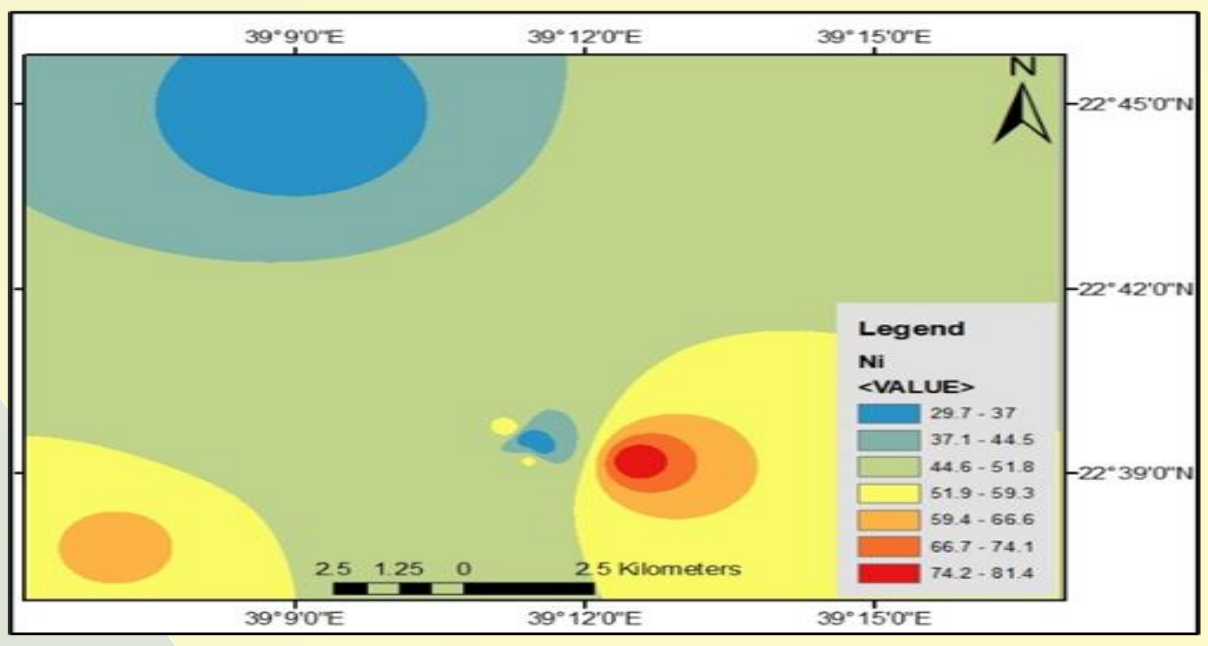
The symbol "s" represents the predicted location. Z(S) is the variable under forecasting. μ(S) is the deterministic trend. ε(S) is the spatially-autocorrelated random error.



The spatial distribution of the groundwater TDS's



The spatial distribution of pH of soil samples



The spatial distribution of Ni (mg/kg) in the soil

Conclusions

The current study explored the impacts of landfill sites on the soil and the groundwater quality in the South-East of Rabigh city. Physical and chemical analyses for major ions and heavy metals were performed on fourteen groundwater samples and seventeen soil samples for heavy metals. The results showed that the groundwater is contaminated with notable levels of TDS, Na+, Ca2+, Mg2+, Cl-, SO42-. Evidence from the main ion chemistry showed that Na+ and Ca2+ were the most prevalent cationic constituents followed by Mg2+. The foremost anions of SO42-, Cl-, HCO3-, and NO3- were found to be sulphate and chloride accompanied by bicarbonate and nitrate compounds. The TDS' spatial distribution shows that groundwater near the landfill is under a great impact on landfill sites. The visualization of the groundwater chemical data from the study area in the Gibbs diagram indicates evaporation is the principal factor affecting the study area's groundwater chemistry. Hydrogeochemical type facies, which are NaCl and CaCl facies, have been identified. The concentration of all the parameters examined was higher in soil than in groundwater, which can be due to the high affinity between soil and element organic matter material. This study suggests an annual monitoring process of the soil for toxic metals present within the vicinity of the study area to assess the impact of landfills and the extent of waste leaching metals.