

The Environmental Impacts of Kabd Landfill on the Soil and Groundwater in Kuwait: A Case Study

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Abstract

The environmental impacts of the Kabd Landfill on the soil and groundwater in Kuwait were evaluated. Physical and chemical analyses were carried out on thirty pairs of surface, subsurface soil and five groundwater samples. The groundwater samples are collected from boreholes nearby and downstream of the landfill while the soil samples collected along six profiles. The groundwater samples were geochemically analyzed to determine the total dissolved solids, cations, anions and heavy metals, particularly Iron (Fe), Copper (Cu), zinc (Zn), Cadmium (Cd), Nickel (Ni), Chromium (Cr) and Aluminum (Al), Lithium (Li), Boron (B), Fluoride (F) and Vanadium (V). The soil samples were geochemically analyzed to determine concentration of Cadmium (Cd), Lead (Pb), Nickel (Ni), Iron (Fe), Aluminum (Al) and organics. The results show that the soil and groundwater are contaminated with high TDS, Na, Ca, Mg, Cl, SO₄ and heavy metals, especially Ni, Cd, Cu, Al, V and F. The heavy metal concentrations in both the soil and groundwater samples are compared to the World Health Organization (WHO) standard permissible limits. The results revealed that the Zn, Li, B and Fe metals are below the WHO limits for consumption. The soil lithology, natures of dumping, the depth of quarry and the depth to the groundwater level play roles in leachate generation and groundwater contaminations. Such leachate may be originated from the capillary fringe water, moisture content and rising water table, due to its close level at the bottom of the waste disposal site. The organic strength of the soil was reduced due to waste decomposition and continuous gas flaring. Re-designing of sanitary landfills to prevent leachate from getting to the groundwater and adoption of clean technology for a sustainable land management program for reclamation is recommended.

Keywords

Environmental Impacts, Landfill, Kuwait, Soil, Groundwater

1. Introduction

The state of Kuwait is situated at the northeastern corner of the Arabian Peninsula. It comprises an area of approximately 17,600 km², with the Geographic Coordinates of 30°20'15"N and 47°39'29"E (**Figure 1**). The landfill sites are considered as an environmental problem for the urban areas. The impacts of these landfills, are growing especially after the urban expansion opened, where some of landfills became inside the residential areas or near to them (**Figure 2**). Some of these landfills are closed, others re-opened to receive thousands of tons per day of waste such as Kabd solid wastes landfill. This landfill was introduced in 1999, to fill the remnants of animal shelters and household waste. It was closed in 2001 and remained closed for more than 10 years before reopening to



Figure 1. The geographical location of Kuwait and its neighboring countries. <https://www.google.com.kw/>

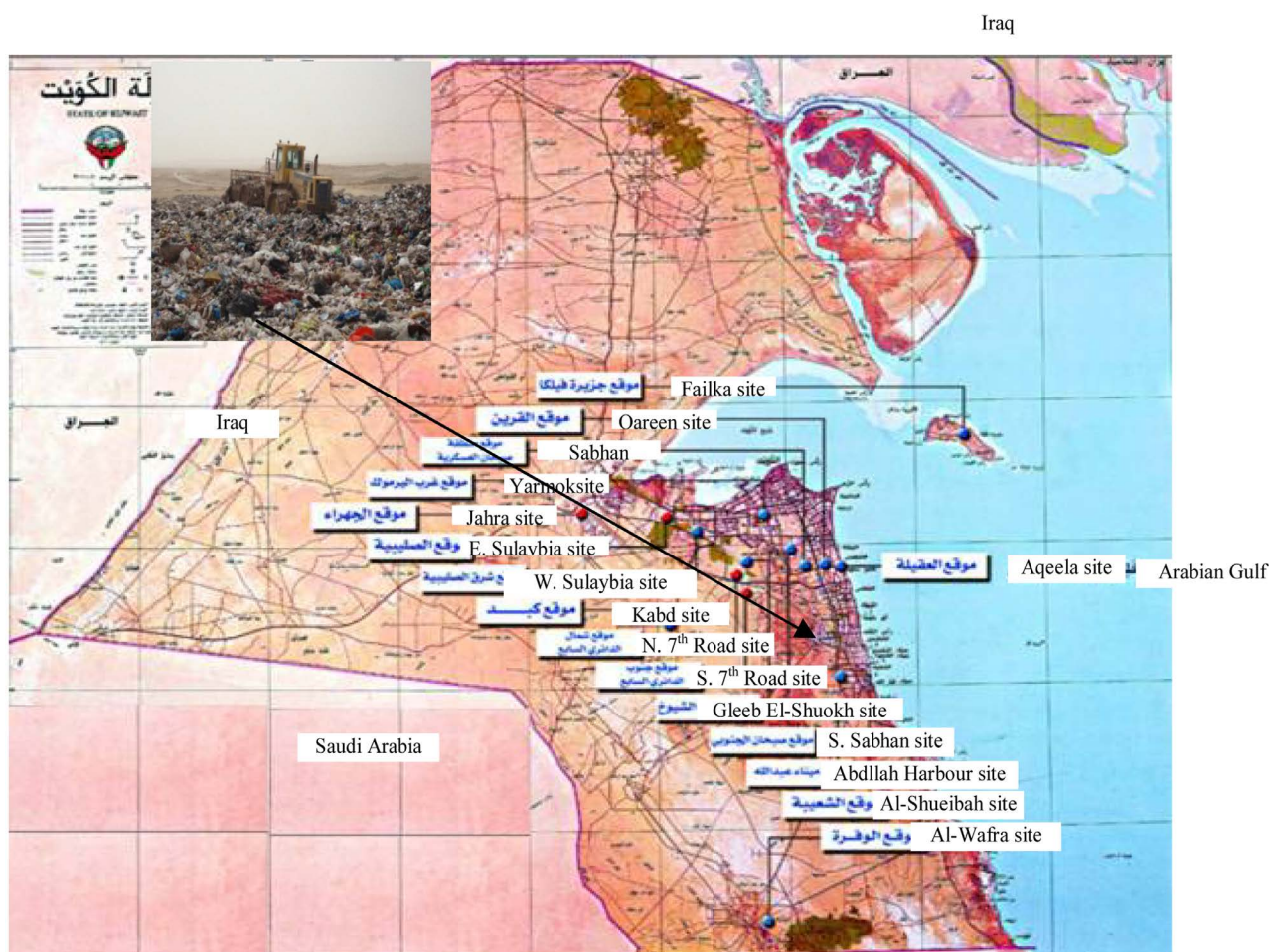


Figure 2. The landfill sites in the state of Kuwait.

receive again different solid and household wastes.

The closure of the waste-dump does not imply the absence of environmental risks. It might be possible that even when sealed, a landfill might contaminate the soils and groundwater of the area. The water moves down into the ground because of gravity, passing between particles of soil, sand, gravel, or rock until it reaches a depth where the ground is filled, or saturated, with water.

The concentration of waste materials in the landfill site had systematically polluted the soil and groundwater over time [1]. The effect of such pollution as determined from the study declined away from the polluting source. This implied that the contamination of the groundwater was more dependent on the proximity to the dump sites. Smaller dependence has been attributed to the influence of topography, type, state of waste disposal systems and, to some extent, hydrogeology of the area.

Groundwater pollution is mainly due to the process of industrialization and urbanization that has progressively developed over time without any regard for environmental consequences [2]. In recent times, the impact of leachate on groundwater and other water resources has attracted a lot of attention because of

its overwhelming environmental significance. Leachate migration from wastes sites or landfills and the release of pollutants from sediments (under certain conditions) pose a high risk to the groundwater resources if not adequately managed [3]. Groundwater protection is a major environmental issue. Open dumps are the oldest and most common way of disposing solid wastes, and although in recent years thousands of them have been closed, many are still being used [4]. The frequently used municipal solid waste disposal methods include: composting, sanitary landfill, and pyrolysis, reuse recovery and recycling [5].

[6] stated that excessive accumulation of heavy metals in agricultural soils through waste water irrigation, may not only result in soil contamination, but also lead to elevated heavy metal uptake by crops, and thus affect food quality and safety [7]. The pollution load index values indicated that the wastewater-irrigated soils were moderately enriched with Cr, Cu, Ni, Pb and Zn, and strongly enriched with Cd. Heavy metals are a potential human health concern when concentrations are at high levels in soils. Breathing dust coming from soil may also pose a health risk. Metals of concern are arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), nickel (Ni), selenium (Se), and zinc (Zn).

The aims of this are to evaluate the impacts of Kabd solid waste landfill, that possible generates a permanent long-term source of pollution to the soil horizon and the groundwater, however to detect the role of groundwater flow direction on the movement of landfill pollutants and to develop appropriate scientific solutions to reduce the landfill impacts.

2. Materials and Methodology

The materials used in the present study include groundwater, surface and subsurface soil samples collected from the landfill site and neighboring areas. Location of the water wells and soil samples are shown in **Figure 3**.

The samples were collected from Jan to June 2016 as follows:

- 1) Five groundwater samples from already drilled water wells, down-stream of the Landfill.
- 2) Thirty pairs of surface and subsurface soil samples along six transect. The subsurface samples are collected by digging a hole of 30 cm depth.

The field observations, related to the landfill waste types, waste sorting and burial methods, have been reported for the subsequent interpretation process. The soil samples are subjected to geochemical analysis in the INCO-LABS (KSCC) to determine the Cadmium, Lead, Nickel, Iron, Aluminum and Organic concentrations using the APHA3120 Method. The groundwater samples are geochemically analyzed to determine the TDS, Chloride, Sulfate, Nitrate, Calcium, Magnesium, Sodium, Potassium, Iron, Copper, Nickel, Zinc, Aluminum, Lithium, Boron and Fluoride concentrations. Processing and illustration of the results of the geochemical analyses data are done using specialized graphs and distribution maps utilizing up-to-date specialized softwares.

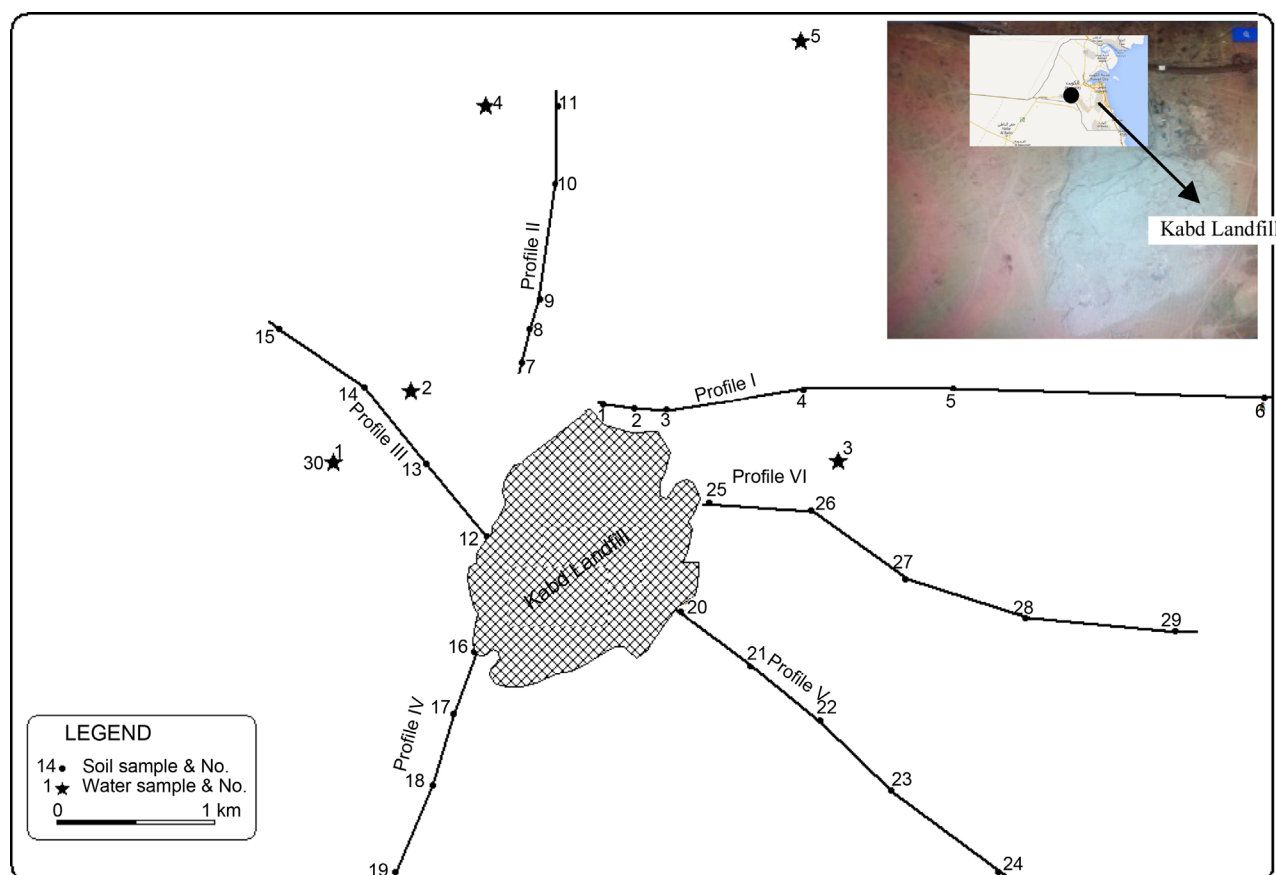


Figure 3. Sample locations of groundwater wells and soil samples around Kabad Landfill.

3. Results and Discussions

3.1. Chemical Analyses of Groundwater

The results of the groundwater chemical analyses are presented in **Table 1**. A very high variation was noted in the concentrations of the total dissolved solids (TDS) that ranged from 9820 to 12,740 mg/L, with high concentrations of chloride (Cl), sulfate (SO_4), sodium (Na), magnesium (Mg) and calcium (Ca), potassium (K). The WHO and environmental quality standards (EQS) for groundwater pollution that were issued in 2013 by the Ministry of the Environment of Japan are tabulated in **Table 1**. The anions and cations concentrations are illustrated using the Pie and Ternary diagrams (**Figure 4(a)** and **Figure 4(b)**) that suggest saline and hard water. The Piper and Durov diagrams (**Figure 4(c)** and **Figure 4(d)**) identify the prominent water type in the study area that was $\text{Ca}^{2+}\text{-Mg}^{2+}\text{-Cl}^{-}\text{-SO}_4^{2-}$ water type.

The lateral distribution of Cl, SO_4 , Na, Mg, Ca and K (**Figure 5**) reveals a tendency to increase downstream N and NE with relatively low nitrate concentrations. By contrast, Cadmium (Cd), chromium (Cr) Vanadium (V) and fluoride (F) concentrations were exceeded the standard levels of World Health Organization (WHO) and tend to decrease downstream far away from the landfill site (**Figure 6**). By contrast, the Nickel (Ni), Aluminum (Al), Boron (B), Lithium

Table 1. Chemical analysis of groundwater samples (mg/L) from and around the study area.

| Test Parameter | Test Method | 1 | 2 | 3 | 4 | 5 | WHO standards for groundwater |
|----------------|-------------------|---------|---------|---------|---------|---------|-------------------------------|
| TDS | | 9820 | 10,420 | 9930 | 12,530 | 12,740 | 500 mg/L or less |
| Chloride | BS1377 Part3 1990 | 3191.40 | 3468 | 4139 | 4012 | 4246 | 250 mg/L or less |
| Sulfate | BS1377 Part3 1990 | 2332.00 | 2478 | 2520 | 2645 | 2670 | 400 mg/L or less |
| Nitrate | BS1377 Part3 1990 | 43 | 43 | 44 | 42 | 42 | 50 mg/L or less |
| Calcium | ASTM D 511 | 828.40 | 831.20 | 833.30 | 845.20 | 849.30 | 75 mg/L or less |
| Magnesium | ASTM D 511 | 303.42 | 309.22 | 311.02 | 324.22 | 330.02 | 100 mg/L or less |
| Sodium | Flame Photometric | 4100.00 | 4280.50 | 4290.20 | 4320.50 | 4327.20 | 35 mg/L or less |
| Potassium | Flame Photometric | 32.00 | 33.00 | 33.70 | 34.40 | 36.50 | 2 mg/L or less |
| Iron | ASTM D 1068 | <0.10 | <0.10 | <0.10 | <0.10 | <0.10 | 0.3 mg/L |
| Cadmium | APHA3120 | 0.007 | 0.006 | 0.006 | 0.005 | 0.005 | 0.003 mg/L or less |
| Chromium | APHA3120 | 0.539 | 0.538 | 0.536 | 0.534 | 0.530 | 0.05 mg/L or less |
| Vanadium | APHA3120 | 0.36 | 0.41 | 0.40 | 0.36 | 0.33 | 40 mg/L or less |
| Copper | Nano Photometric | 0.17 | 0.17 | 0.16 | 0.13 | 0.11 | 7 mg/L or less |
| Nickel | Nano Photometric | 0.52 | 0.52 | 0.51 | 0.49 | 0.48 | 1.3 mg/L or less |
| Zinc | Nano Photometric | 0.64 | 0.68 | 0.63 | 0.60 | 0.59 | 20 mg/L or less |
| Aluminum | APHA3120 | 0.28 | 0.27 | 0.25 | 0.23 | 0.20 | 5 mg/L or less |
| Lithium | APHA3120 | 0.24 | 0.24 | 0.23 | 0.21 | 0.19 | 50 mg/L or less |
| Boron | APHA3120 | 0.02 | 0.02 | 0.02 | 0.01 | 0.01 | 1 mg/L or less |
| Fluoride | APHA3120 | 1.1 | 1.05 | 1.09 | 0.95 | 0.90 | 0.8 mg/L or less |

(Li), Zinc (Zn) and Iron (Fe) show low levels of concentrations.

3.2. Chemical Analyses of Soil

The results of chemical analysis of 30 pairs of surface and subsurface soil samples are illustrated in **Figure 7** and tabulated (profile-wise) with the WHO standard permissible values as shown in **Table 2**.

The results indicate high concentration of heavy metals in soil samples than the WHO's standard values (**Table 2**). These high concentrations were recorded in both the surface and subsurface soil samples with a tendency to increase in the subsurface samples especially for Ni, Al and Fe.

To clarify the impact of the landfill on the groundwater contamination, particularly with heavy metals, a chart (**Figure 8**) was constructed to compare the concentration and distribution of heavy metals in the surface, subsurface soils and the groundwater.

This chart shows that the concentration of Cd (**Figure 8(a)**), Ni (**Figure 8(b)**) and Al (**Figure 8(c)**) were generally high and exceed in the subsurface soils samples than their surface concentrations, except the Cd, with a tendency to increase S and SE wards far away from the landfill. The concentrations of these elements in the downstream groundwater samples shows high concentration near the landfill site and gradually decrease N and NE wads with the directions

Table 2. Chemical analysis of soil samples (mg/kg) of the Kabd Landfill.

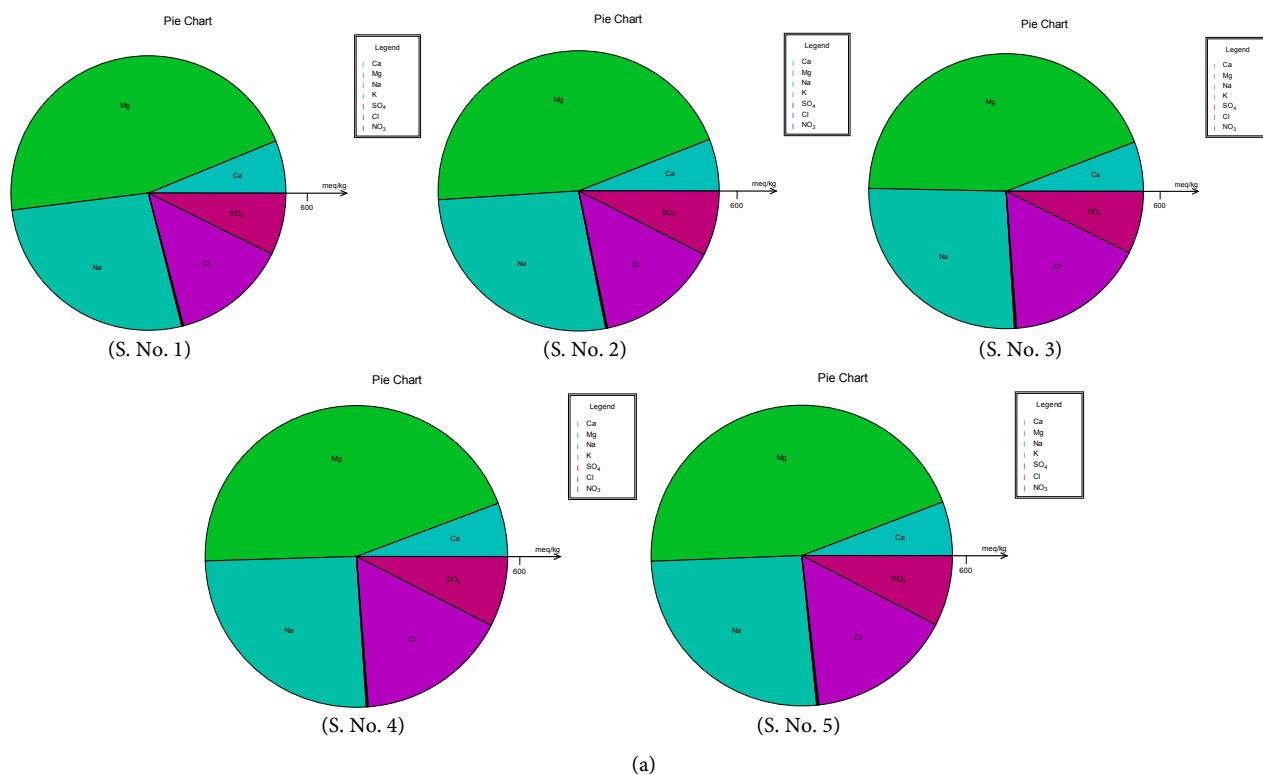
| Profile No. | Sample No. | Sample Status | hemical Analysis of soil samples (mg/kg) | | | | | |
|-------------|------------|---------------|--|-------|-------|----------|----------|----------|
| | | | Cd | Pb | Ni | Fe | Al | Organics |
| I | 1 | surface | 0.140 | 2.776 | 5.79 | 2607.283 | 2618.314 | 0.042 |
| | | subsurface | 0.191 | 1.433 | 9.005 | 2434.394 | 1923.894 | 0.034 |
| | 2 | surface | 0.144 | 2.766 | 5.76 | 2602.1 | 2614.200 | 0.041 |
| | | subsurface | 0.193 | 1.432 | 9.111 | 2431.250 | 1921.190 | 0.193 |
| | 3 | surface | 0.141 | 2.746 | 5.56 | 2599.7 | 2609.500 | 0.039 |
| | | subsurface | 0.181 | 1.633 | 9.018 | 2417.210 | 1909.610 | 0.029 |
| | 4 | surface | 0.139 | 2.726 | 5.26 | 2579.1 | 2601.200 | 0.032 |
| | | subsurface | 0.127 | 1.936 | 8.961 | 2361.152 | 1894.020 | 0.021 |
| | 5 | surface | 0.137 | 2.700 | 5.01 | 2559.2 | 2591.400 | 0.028 |
| | | subsurface | 0.112 | 2.131 | 8.343 | 2311.210 | 1866.220 | 0.017 |
| | 6 | surface | 0.120 | 2.676 | 4.86 | 2529.3 | 2573.700 | 0.019 |
| | | subsurface | 0.0979 | 2.773 | 7.943 | 2278.050 | 1852.340 | 0.010 |
| | 7 | surface | 0.341 | 3.111 | 9.14 | 2438.22 | 1931.050 | 0.042 |
| | | subsurface | 0.263 | 2.737 | 24.10 | 5745.142 | 4442.021 | 0.032 |
| | 8 | surface | 0.334 | 3.08 | 9.05 | 2434.394 | 1923.894 | 0.036 |
| | | subsurface | 0.258 | 2.717 | 23.97 | 5733.178 | 4425.069 | 0.030 |
| II | 9 | surface | 0.334 | 3.08 | 9.05 | 2434.394 | 1923.894 | 0.036 |
| | | subsurface | 0.231 | 2.702 | 23.75 | 5722.126 | 4405.213 | 0.026 |
| | 10 | surface | 0.326 | 3.001 | 8.89 | 2422.11 | 1903.310 | 0.026 |
| | | subsurface | 0.213 | 2.685 | 23.36 | 5702.111 | 4395.122 | 0.021 |
| | 11 | surface | 0.311 | 2.981 | 8.72 | 2409.17 | 1889.150 | 0.019 |
| | | subsurface | 0.184 | 2.672 | 22.95 | 5692.421 | 4382.231 | 0.018 |
| | 12 | surface | 0.356 | 3.225 | 9.25 | 2451.236 | 1942.520 | 0.053 |
| | | subsurface | 0.284 | 2.752 | 24.92 | 5754.113 | 4453.211 | 0.043 |
| III | 13 | surface | 0.349 | 3.119 | 9.19 | 2442.33 | 1935.620 | 0.048 |
| | | subsurface | 0.271 | 2.743 | 24.56 | 5749.261 | 4449.102 | 0.039 |
| | 14 | surface | 0.341 | 3.111 | 9.14 | 2438.22 | 1931.050 | 0.042 |
| | | subsurface | 0.263 | 2.737 | 24.10 | 5745.142 | 4442.021 | 0.032 |
| | 15 | surface | 0.334 | 3.08 | 9.05 | 2434.394 | 1923.894 | 0.036 |
| | | subsurface | 0.258 | 2.717 | 23.97 | 5733.178 | 4425.069 | 0.030 |
| | 16 | surface | 0.356 | 3.225 | 9.25 | 2451.236 | 1942.520 | 0.053 |
| | | subsurface | 0.284 | 2.752 | 24.92 | 5754.113 | 4453.211 | 0.043 |

Continued

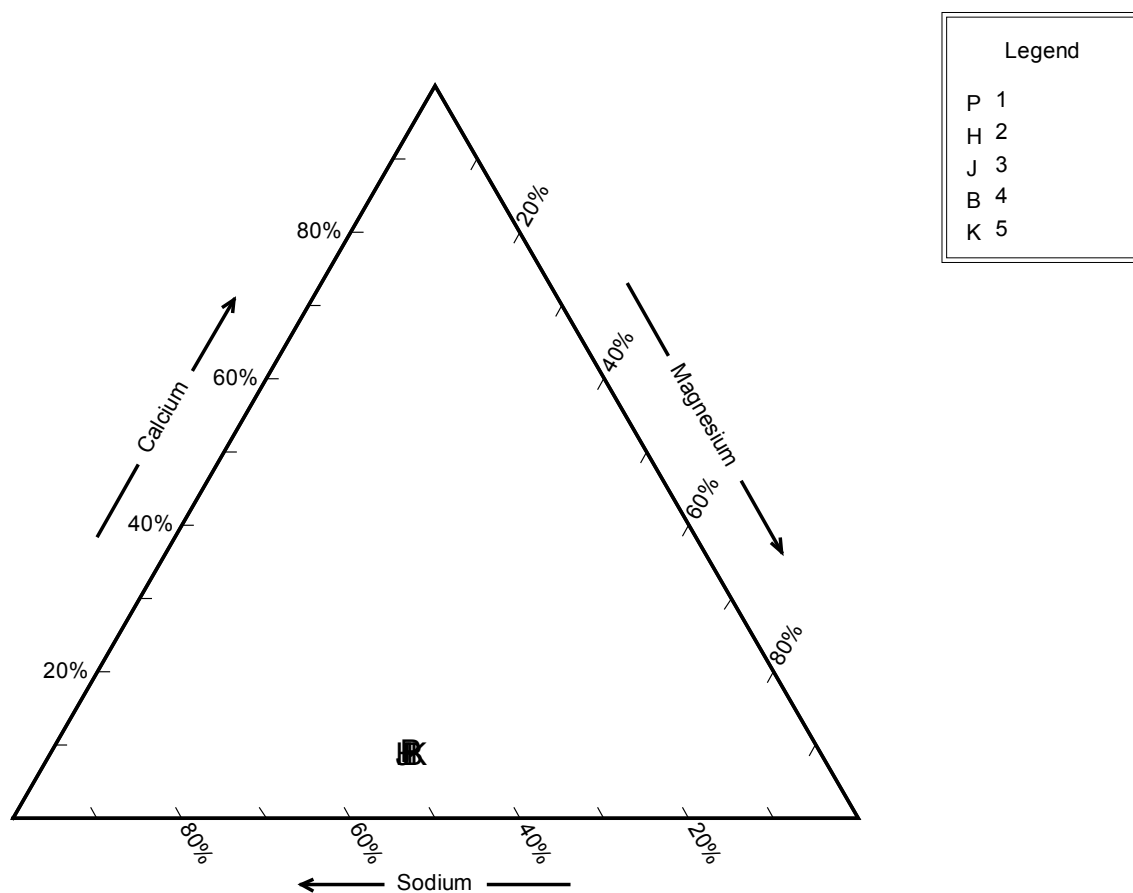
| | | | | | | | | | |
|----|---|------------|---------|--------------------|----------------------|---------------------|-------------------------|----------|-------|
| IV | 17 | surface | 0.364 | 3.231 | 9.29 | 2459.263 | 1951.230 | 0.061 | |
| | | subsurface | 0.295 | 2.762 | 25.61 | 5759.612 | 4459.241 | 0.056 | |
| | 18 | surface | 0.372 | 3.242 | 9.35 | 2463.215 | 1958.210 | 0.069 | |
| | | subsurface | 0.302 | 2.779 | 25.98 | 5768.126 | 4465.321 | 0.069 | |
| | 19 | surface | 0.381 | 3.251 | 9.42 | 2471.256 | 1965.320 | 0.075 | |
| | | subsurface | 0.311 | 2.785 | 26.31 | 5772.611 | 4471.521 | 0.078 | |
| V | 20 | surface | 0.356 | 3.225 | 9.25 | 2451.236 | 1942.520 | 0.053 | |
| | | subsurface | 0.284 | 2.752 | 24.92 | 5754.113 | 4453.211 | 0.043 | |
| | 21 | surface | 0.364 | 3.231 | 9.29 | 2459.263 | 1951.230 | 0.061 | |
| | | subsurface | 0.295 | 2.762 | 25.61 | 5759.612 | 4459.241 | 0.056 | |
| | 22 | surface | 0.372 | 3.242 | 9.35 | 2463.215 | 1958.210 | 0.069 | |
| | | subsurface | 0.302 | 2.779 | 25.98 | 5768.126 | 4465.321 | 0.069 | |
| | 23 | surface | 0.381 | 3.251 | 9.42 | 2471.256 | 1965.320 | 0.075 | |
| | | subsurface | 0.311 | 2.785 | 26.31 | 5772.611 | 4471.521 | 0.078 | |
| | 24 | surface | 0.395 | 3.260 | 9.56 | 2476.261 | 1970.320 | 0.085 | |
| | | subsurface | 0.356 | 2.802 | 26.64 | 5781.23 | 4480.214 | 0.083 | |
| | 25 | surface | 0.356 | 3.225 | 9.25 | 2451.236 | 1942.520 | 0.053 | |
| | | subsurface | 0.284 | 2.752 | 24.92 | 5754.113 | 4453.211 | 0.043 | |
| VI | 26 | surface | 0.364 | 3.231 | 9.29 | 2459.263 | 1951.230 | 0.061 | |
| | | subsurface | 0.295 | 2.762 | 25.61 | 5759.612 | 4459.241 | 0.056 | |
| | 27 | surface | 0.372 | 3.242 | 9.35 | 2463.215 | 1958.210 | 0.069 | |
| | | subsurface | 0.302 | 2.779 | 25.98 | 5768.126 | 4465.321 | 0.069 | |
| | 28 | surface | 0.381 | 3.251 | 9.42 | 2471.256 | 1965.320 | 0.075 | |
| | | subsurface | 0.311 | 2.785 | 26.31 | 5772.611 | 4471.521 | 0.078 | |
| | 29 | surface | 0.395 | 3.260 | 9.56 | 2476.261 | 1970.320 | 0.085 | |
| | | subsurface | 0.356 | 2.802 | 26.64 | 5781.23 | 4480.214 | 0.083 | |
| | Sample | 30 | surface | 0.007 | 1.302 | 16.19 | 4470.107 | 3559.259 | 0.072 |
| | WHO Standard Values in sample solution | | | 3 mg/kg or less | 100 mg/kg or less | 50 mg/Kg or less | 50,000 mg/kg or less | | |

of groundwater flow. This indicates that the Cd, Ni and Al contamination may be attributed to the landfill with a considerable level of confidence.

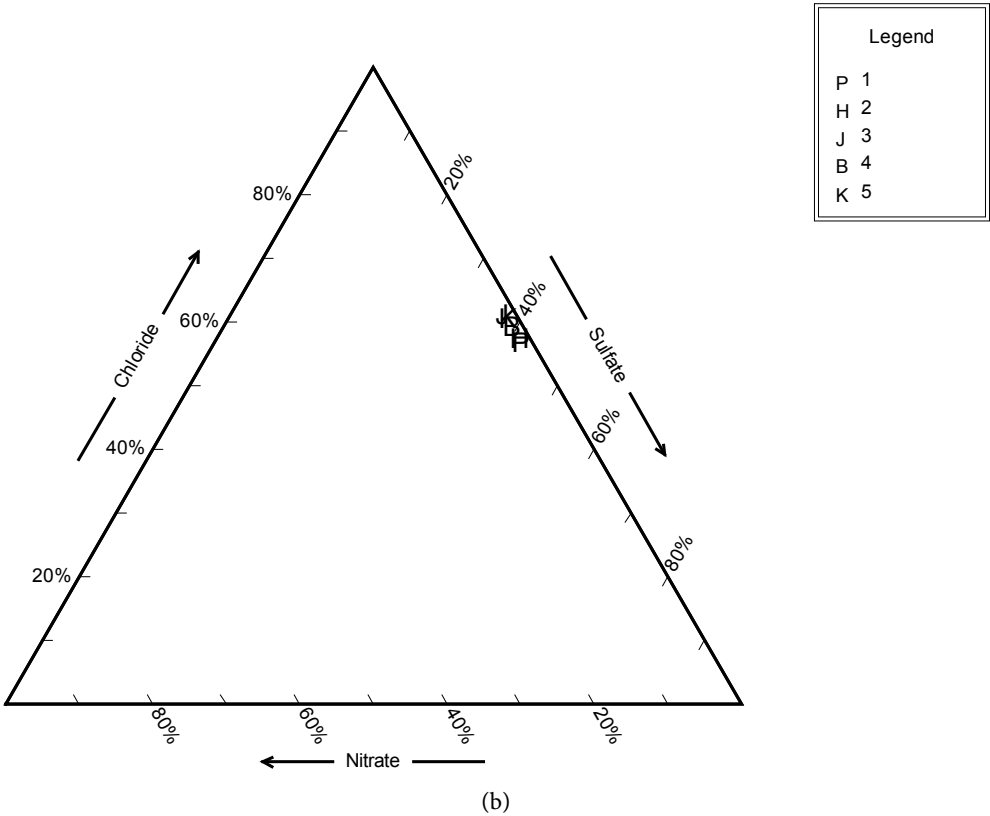
The transmission of these elements from the surface to the groundwater depends on the soil lithology, natures of dumping, the depth of quarry and the depth to the groundwater level. The major method of solid waste disposal prevailing in Kuwait is open dumping in abandoned sand quarries with an average



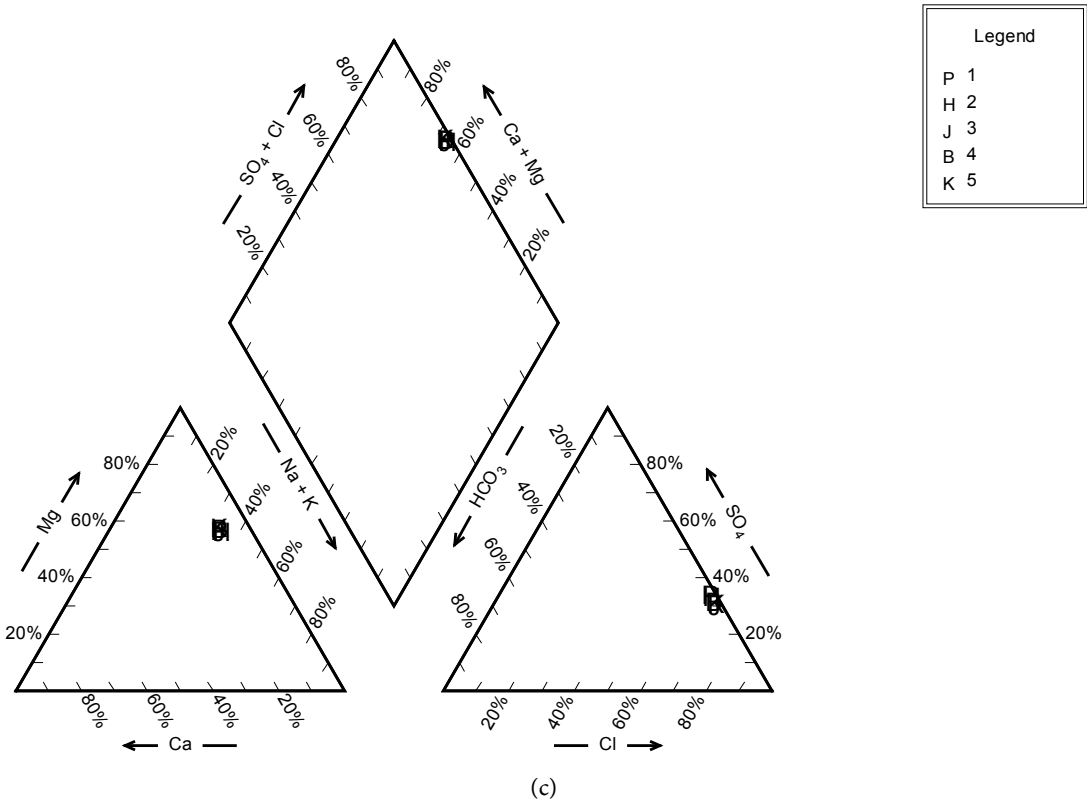
Ternary Diagram



Ternary Diagram



Piper Diagram



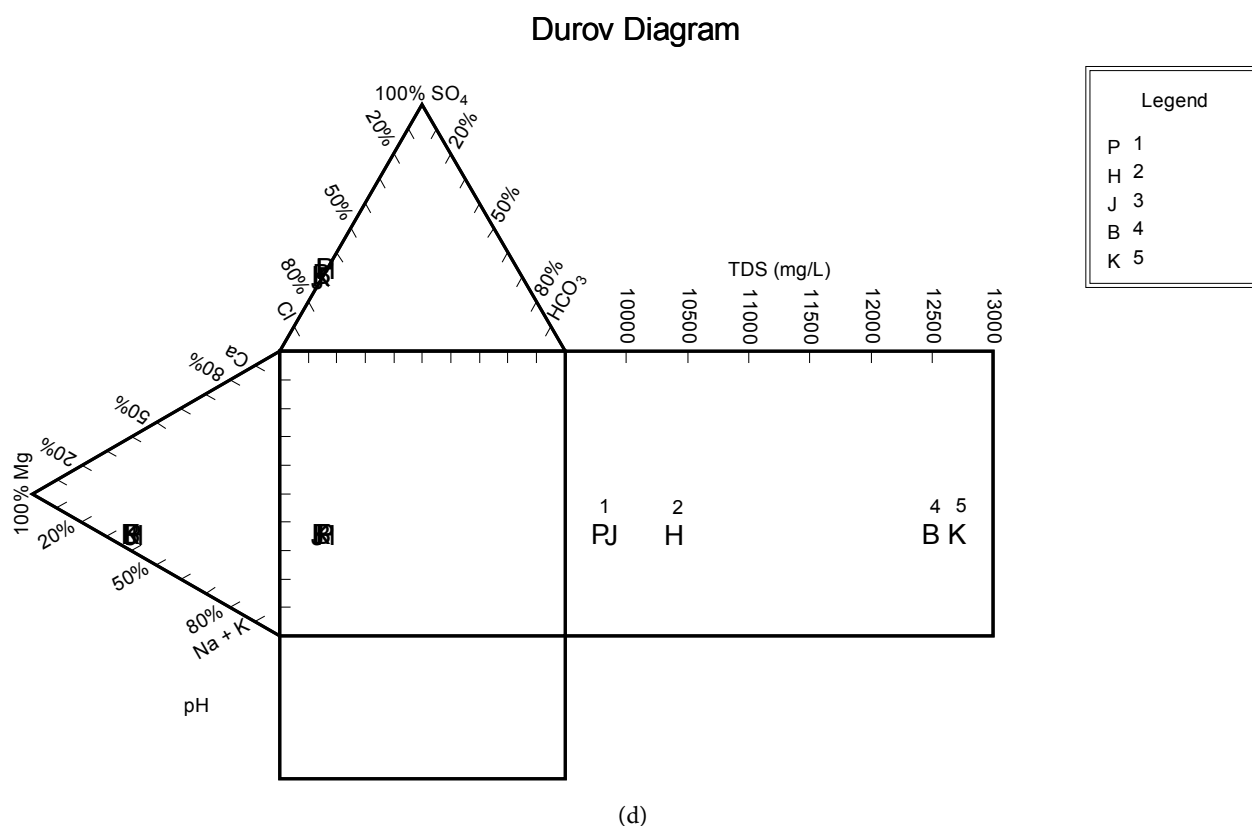


Figure 4. Pie (a), Ternary (b), Piper (c) and Durov (d) diagrams illustrate the anions and cations of the groundwater samples.

depth of 5 - 18 m, then covering the waste with sand but without compaction or any protection system [8]. Therefore, contamination of the groundwater is possible due to its close level at the bottom of the waste disposal site.

On the contrary, in spite of the iron (Fe) concentration in the surface and subsurface soil samples exhibits was high and attains the same distribution pattern in the study area (Figure 9), the Fe concentration in the groundwater samples is very low (under the detecting limit < 0.1 , Table 1). This reverse relationship may be attributed to the Fe dissolving habit, which depends on the amount of oxygen in the groundwater and, to a lesser extent, upon its degree of acidity [9]. Iron, for example, can occur in two forms: as Fe^{2+} and as Fe^{3+} . When levels of dissolved oxygen in groundwater are greater than 1 - 2 mg/L, iron occurs as Fe^{3+} , while at lower dissolved oxygen levels, the iron occurs as Fe^{2+} . Although Fe^{2+} is very soluble, Fe^{3+} will not dissolve appreciably. If the groundwater is oxygen poor, iron (and manganese) will dissolve more readily, particularly if the pH of the water is on the low side (slightly more acidic).

Dissolved oxygen content is typically low in deep aquifers, particularly if the aquifer contains organic matter. Decomposition of the organic matter depletes the oxygen in the water and the iron dissolves as Fe^{2+} . Under these conditions, the dissolved iron is often accompanied by dissolved manganese or hydrogen sulfide. When this water is reached to the surface, the dissolved iron reacts with the atmospheric oxygen, changes to Fe^{3+} (*i.e.*, is oxidized) and forms rust-colored

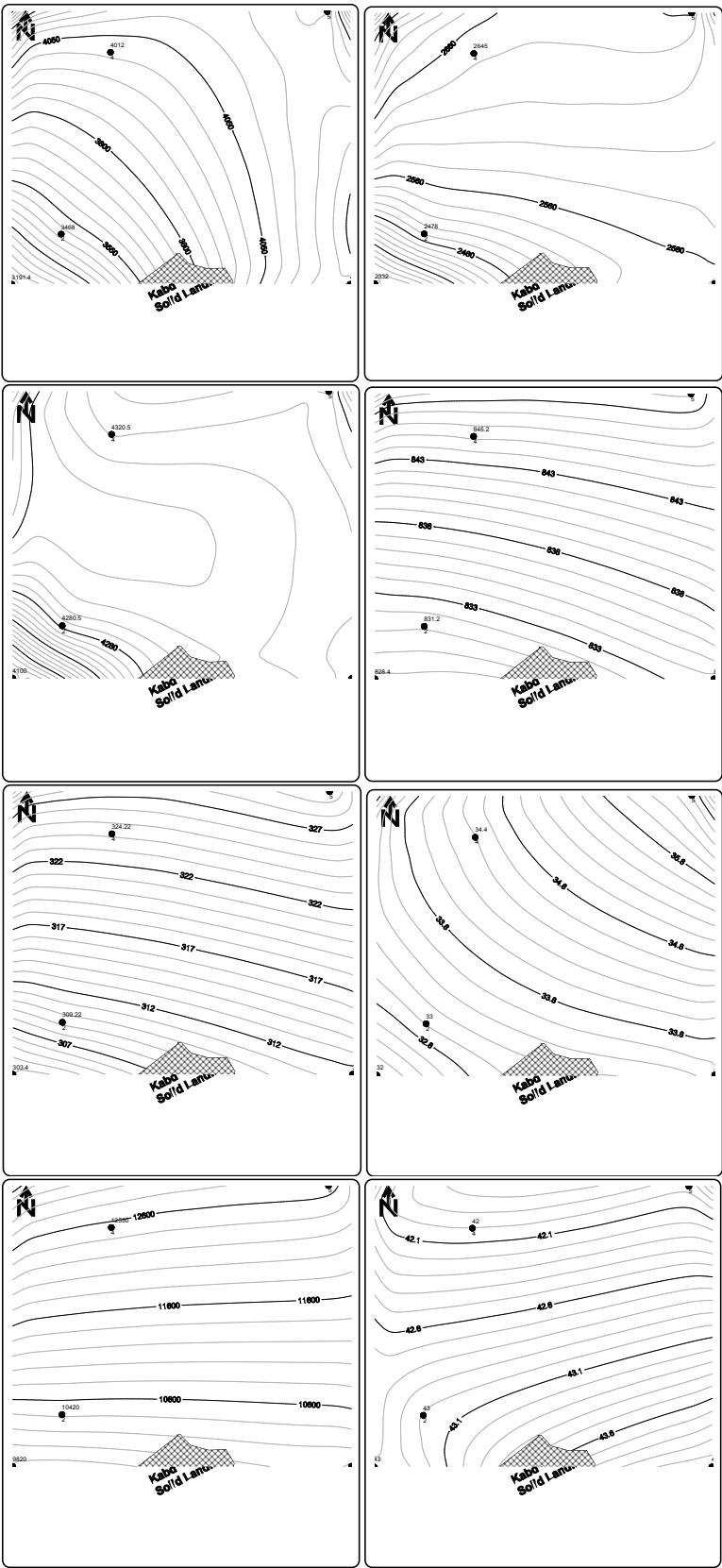


Figure 5. Contour maps show distribution of the TDS, cations and anions in the groundwater samples.

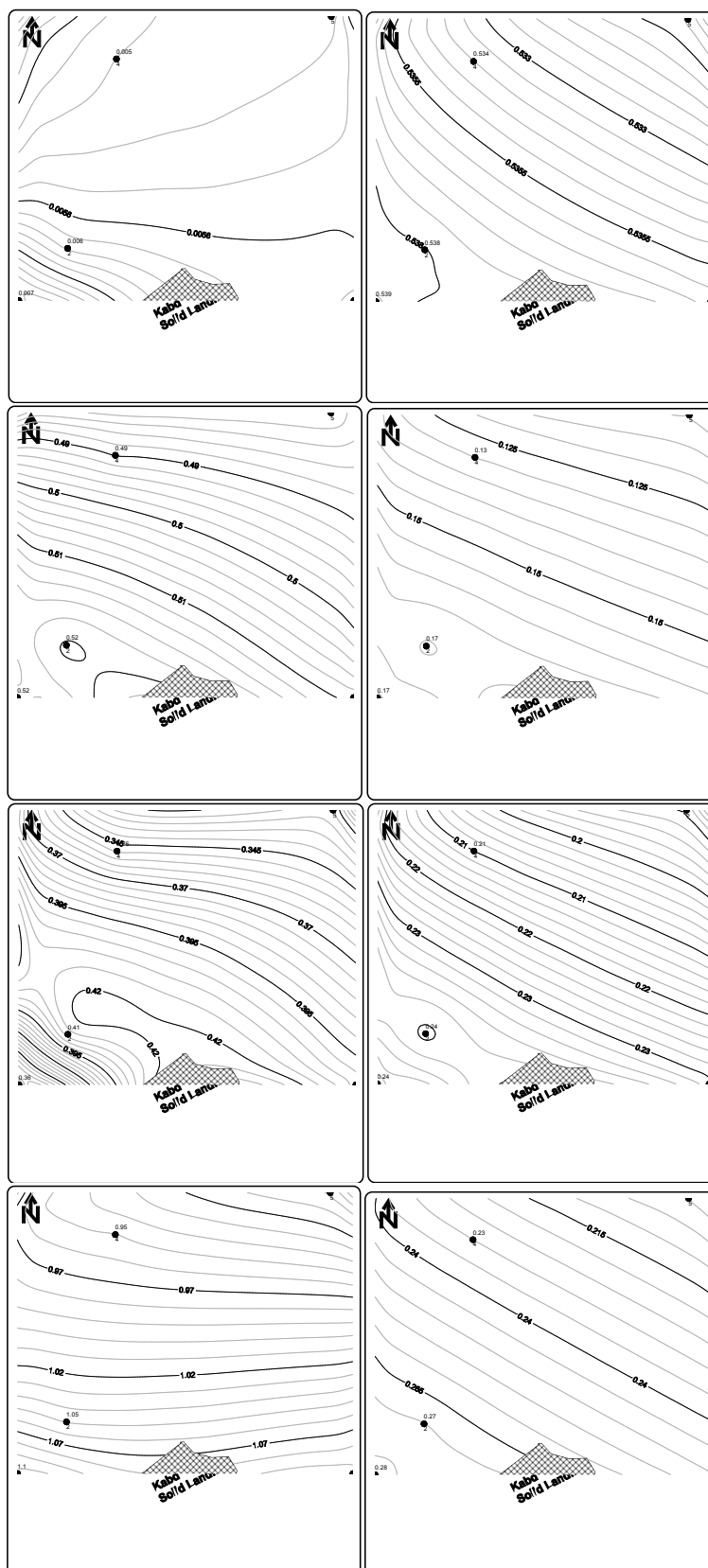


Figure 6. Contour maps show distribution of the heavy metals in the groundwater samples.

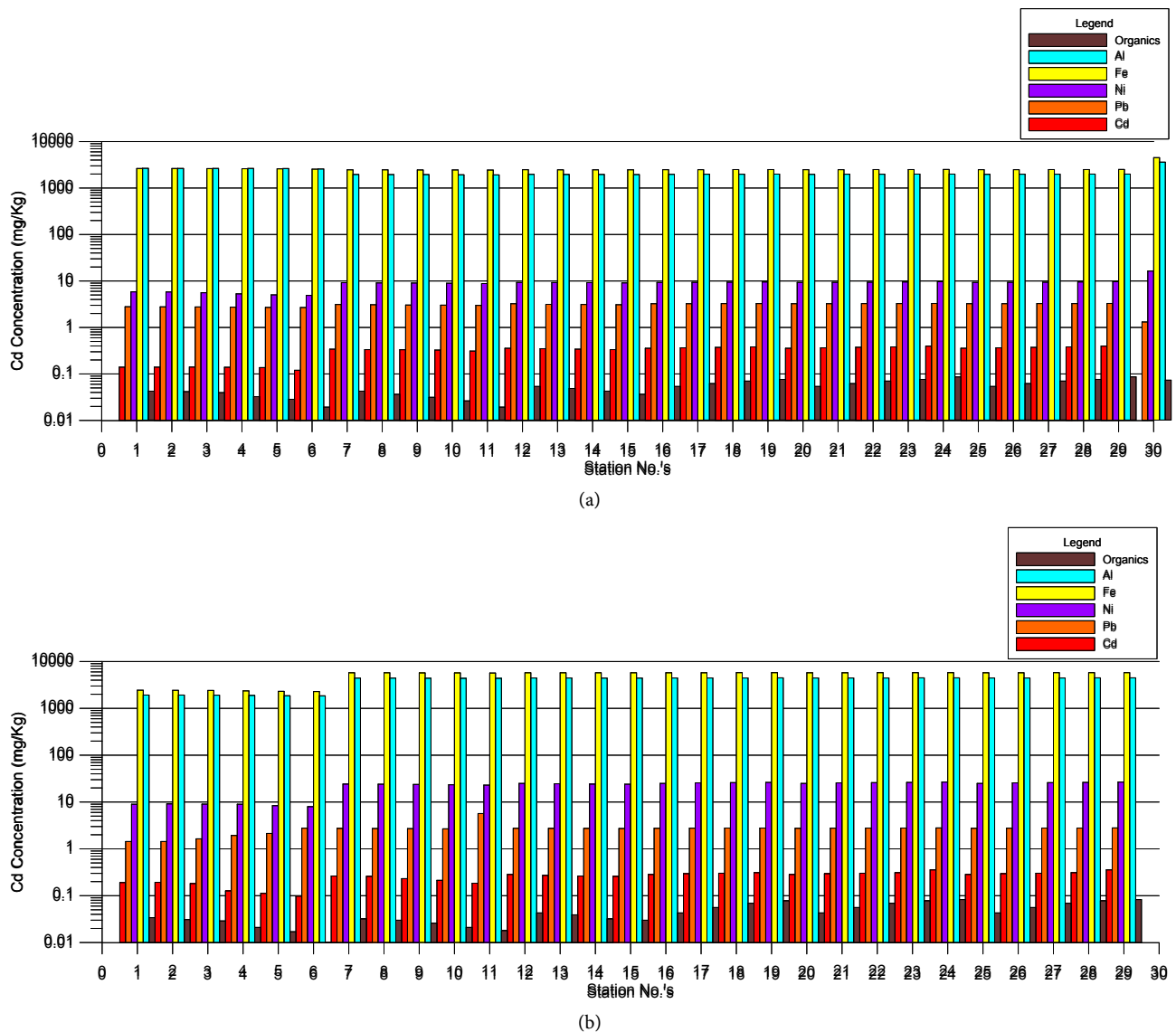


Figure 7. Heavy metal concentrations (mg/kg) in surface (a) and subsurface (b) soil samples.

iron minerals [9]. Accordingly, the amount of dissolved iron in groundwater may vary seasonally for a given well. Usually this is associated with an influx of oxygenated water from the surface during periods of high recharge. This oxygenated water will prevent the iron from dissolving and the water pumped from the well will have low concentrations of these metals. After consuming the oxygen in, iron will again be dissolved and the water will have dissolved iron characteristics.

4. Conclusions

The research deals with evaluation of the environmental impacts of the Kabd Landfill on the soil and groundwater. Physical and chemical analyses were carried out on five groundwater samples collected from boreholes nearby and downstream of the landfill and thirty pairs of surface and subsurface soil samples

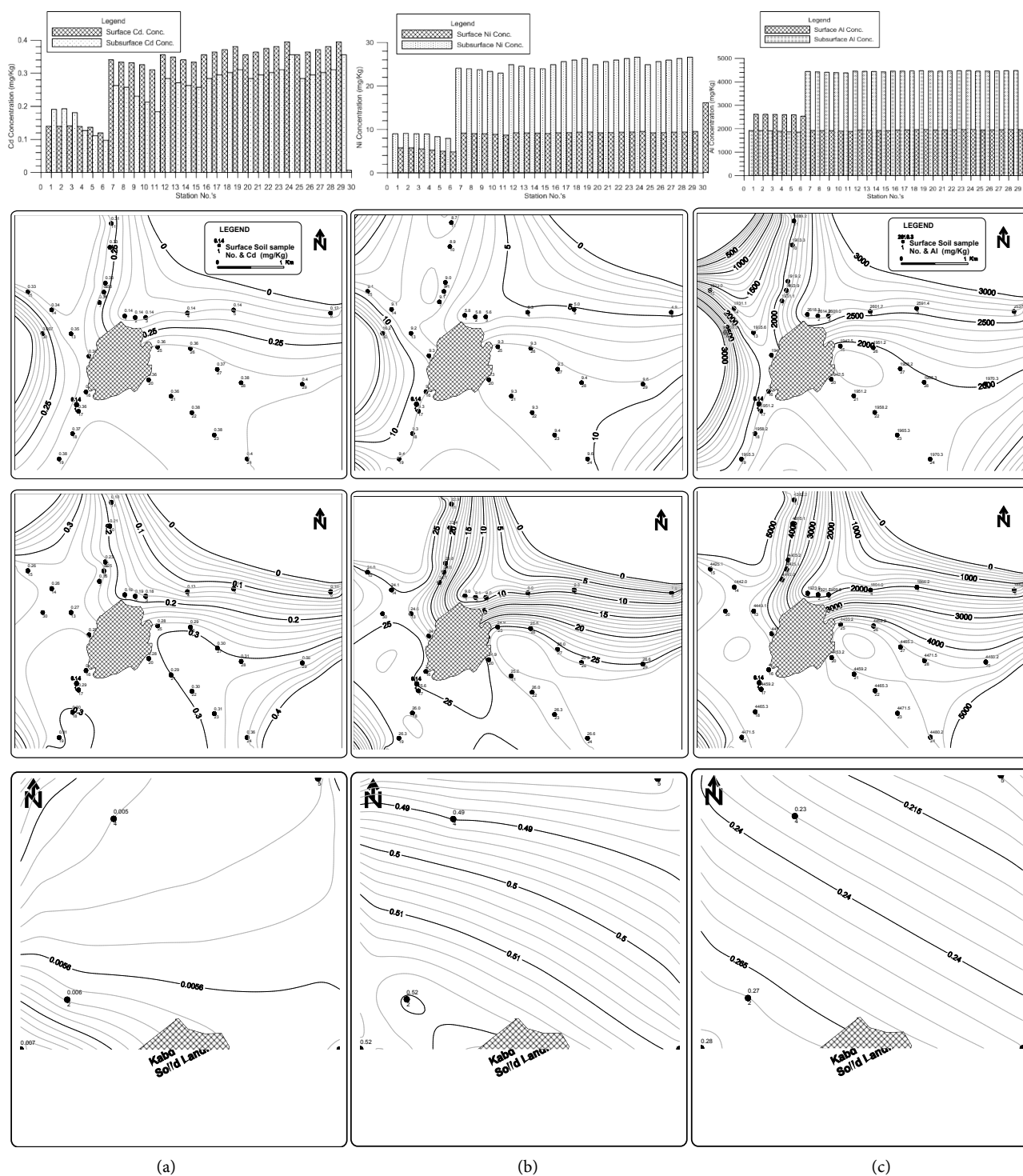


Figure 8. A chart shows comparison of Cd (a), Ni and Al (c) concentrations in the surface and subsurface soil samples of the Kabd Landfill area and their concentrations in the groundwater.

collected along six profiles. The groundwater samples are geochemically analyzed to determine the total dissolved solids, cations, anions and heavy metals, particularly Iron (Fe), Copper (Cu), zinc (Zn), Cadmium (Cd), Nickel (Ni), Chromium (Cr) and Aluminum (Al), Lithium (Li), Boron (B), Fluoride (F) and

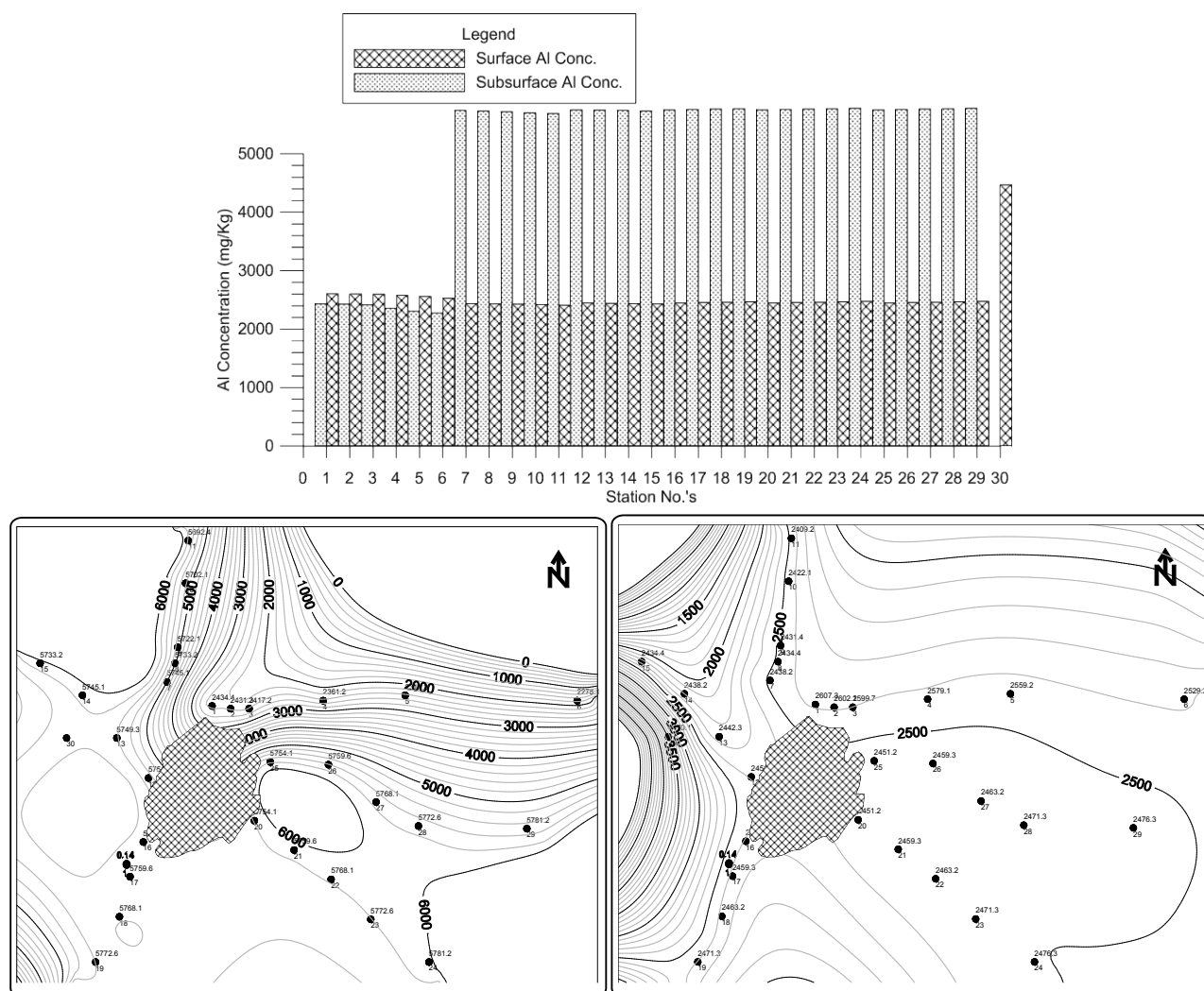


Figure 9. A comparison chart of Fe concentrations in the surface and subsurface soil samples.

Vanadium (V). The soil samples are geochemically analyzed to determine concentration of Cadmium (Cd), Lead (Pb), Nickel (Ni), Iron (Fe), Aluminum (Al).

The results are graphically illustrated and the heavy metals concentrations are compared to the WHO standard permissible limits. Such comparison shows that the soil and groundwater were contaminated with high TDS, Na, Ca, Mg, Cl, SO_4 and heavy metals, especially Ni, Cd, Cu, Al, V and F. The deduced Zn, Li, B and Fe metals are below the World Health Organization (WHO) limits for consumption. However, the organic strength of the soil was reduced due to waste decomposition and continuous gas flaring. The iron (Fe) concentration shows reverse pattern of distribution, *i.e.* it shows very low concentrations in the groundwater samples with high concentrations in the surface and subsurface soil samples. It could be attributed to the Fe dissolving habit, which depends on the amount of oxygen in the groundwater and, to a lesser extent, upon its degree of acidity.

Interpretation of the results, in the context of the surface and subsurface geo-

logical and hydrogeological conditions, points to the role of the soil lithology, natures of dumping, the depth of quarry and the depth to the groundwater level in leachate generation. Such leachate may be originated from the capillary fringe water, moisture content and rising water table, due to its close level at the bottom of the waste disposal site. The research is recommended that the Landfill needs modern methods of filling and/or sorting processing of the wastes components, and re-designing of sanitary landfills to prevent leachate.

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