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Assessment of Influence of Landfill Leachate on Groundwater Quality: A Case Study Albourz Landfill (Qom, Iran)

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Background and Aim of the Study: The landfill leachate is contains various contaminates that can effect on quality of surface water and wells. In this study influence of the leachate from Albourz landfill in Qom (Qom, Iran) was investigated on quality of groundwater.

Material and Methods: In this experimental study, Samples were collected from wells around the landfill site. Various physical, chemical and biological parameters were detected. All tests were performed according to the Standard methods for the examination of water and wastewater. Findings were compared with Iran national drinking water standard.

Results: Findings show that the highest level of pH 7.76 mg/l, nitrate34.12 mg/l, phosphate 8.84 mg/l, total hardness 2095 mg/l, electrical conductivity 14850 µs/cm, total dissolved solids 5841 mg/l, Ca^{+2} 2.5 mg/l, Mg^{+2} 30.11 mg/l, Na^{+} 112 mg/l, K^{+} 28.8 mg/l, Cl^{-}66.75 mg/l, SO_4^{2-} 110.1 mg/l and biological oxygen demand 4.5 mg/l . The results of microbiological tests were reported negative.

Conclusion: Results obtained in this study confirm that the quality of the groundwater resource underlying Albourz landfill hasn't been significantly impacted. The results of experiment of the following specific parameters Po_4^{3-} , TH and TDS are above the highest permissible levels allowed by Iran national Standards for Drinking Water.

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Background

The quantity and quality of municipal solid waste (MSW) depends on various factors such as population, life style, food habit, standard of living, the extent of industrial and commercial activities in the area, cultural tradition of inhabitants, climate. As per the future prediction, the amount of waste generated around the world which stands at 12.7 billion tones in 2000 will be increase to approximately 19 billion tones in 2025 and to approximately 27 billion tones in 2050 (1). By increasing demand for larger space to the disposal of wastes generated from urban areas makes landfill site a necessary component of the urban life cycle (1-3). Landfill sites that is commonly present in urban areas is often related to potential environmental pollution of groundwater or surface water, and in that manner pose a risk to human health as well (4). In operation of landfill period, leachates are produced, mostly due to the infiltration of rainwater through the refuse tips (5). After the waste is disposed of in a landfill, there is a shift from a short acidic phase (aerobic) to much longer acidogenic and methanogenic phases (anaerobic decomposition). During the methanogenic phase, methanogenic bacteria such as methanogenic archaea degrade the volatile fatty acids (VFAs) and reduce the organic strength of leachate, leading to a pH higher than 7 (6). The leachate from a landfill contains a large variety of different substances, both inorganic and organic (7), such as hazardous compounds, including aromatics, halogenated compounds, phenols, pesticides, heavy metals, and ammonium, which can be assumed to be hazardous even in small amounts and their detrimental effects are often caused by multiple and synergistic effects (8). The concentrations of some leachate composition in terms of average values and ranges for parameters with differences between acid and methanogenic phase and average values for parameters with no observed differences between acid and methanogenic phase are presented in Table 1. Table 1 show that the cations such as calcium, magnesium and iron are lower in methanogenic phase leachate due to a higher pH (9).

Groundwater contamination can occur by infiltration recharge from surface water, direct migration and inter-aquifer exchange. The first and second mechanisms primarily affect surface aquifers and the third and fourth may affect both surface and, deep aquifers. The impact of landfill leachates on the surface and ground-water has given rise to a great number of studies in recent years (10). Contaminant transport through composite landfill liners can be considered in two problems: (1) transport of inorganic and organic contaminants through defects in the geomembrane seams connecting geomembranes and through clay liner underlying the geomembrane, and (2) diffusive transport of organic contaminants through non-defective composite liners (8).

Therefore, there has been increased emphasis on landfill leachate management in the recent years especially for municipal areas (11-13). The impact of landfill on groundwater has been investigated by different researchers with different objectives. In Fernando et al. study on "non-agricultural sources of groundwater nitrate", has been concluded the major sources of nitrogen in urban aquifers are related to solid waste disposal (14).

Table1) Common Leachate Compositions

Parameters	Acid Phase		Methane Phase		Average
	Range	Average	Range	Average	
pH	6.1	4.5-7.5	8	7.5-9	-
BOD (mg/l)	13000	4000- 400000	180	20-550	-
COD (mg/l)	22000	6000- 60000	3000	500 - 450	-
Sulfate (mg/l)	500	70- 1750	80	10- 420	-
Magnesium(mg/l)	47	50- 150	180	40-350	-
Iron(mg/l)	780	20-2100	15	3- 280	-
Chloride(mg/l)	-	-	-	-	740
Phosphate(mg/l)	-	-	-	-	2120
Sodium(mg/l)	-	-	-	-	1085
Lead(mg/l)	-	-	-	-	0.095
Copper(mg/l)	-	-	-	-	0.065
Cadmium(mg/l)	-	-	-	-	0.005

Adeyemi et al. findings showed significantly higher concentration of heavy metals contain Pb (Lead), Cd (Cadmium) and Cr (Chromium) and Coliform bacteria such as E.coli and Shigella were observed in the leachate-contaminated groundwater samples (15). Singh et al. conducted a study on " Assessment of the impact of landfill on groundwater quality", Results suggest the existence of a relationship between some specific indicator parameters like heavy metals of all three above mentioned sample type. Further, k/mg ratio also indicates three groundwater samples heavily impacted from leachate contamination (1).

The Albourz landfill site is located vicinity Qom, in Kooh Sefid road (Qom, Iran). The annual precipitation in this semi-arid region is very low and there are no surface water streams around it. Land fill site is situated wide valley and its soil consists of sand 58%, silt 24% and clay 18% as well. Soil permeability is moderate, so that the soil is capable of 29% of the weight of the soil to hold water. Qom municipal wastes content high moisture and are prone to producing leachate.

Aim of the study: The present study aims to develop an understanding of the natural groundwater quality in the Albourz landfill and the adjacent areas through the wells that have been selected for this purpose and assessment of the impact of Albourz landfill leachate on physicochemical and biological quality of groundwater.

Materials & Methods

This experimental study has been done in laboratory of environmental health engineering, school of public health, Qom University of medical sciences (Qom, Iran). Samples were collected from ten wells around the landfill site. Water samples were collected in 1 liter plastic containers and prior to collection as part of our quality control measures all the bottles were washed with nonionic detergent and rinsed with de-ionized water prior to usage. Before the final water sampling was done, the bottles were rinsed three times with well water at the point of collection. Each bottle was labeled according to sampling location while all the samples were preserved at 4ºC and transported to the laboratory.

Various physical, chemical and biological parameters were estimated, includes pH, total hardness (TH), electrical conductivity (EC), and total dissolved solids (TDS) for the physical parameters. The chemical parameters included are major cations ofCa^{+2}(calcium), Mg^{+2} (magnesium), Na^{+} (sodium), and K^{+} (potassium), and Major anions of Cl^{-}(chloride), SO_4^{2-} (sulfate), Po_4^{3-} (phosphate) and NO_3^{-} (nitrate) and biological parameters contain biological oxygen demand (BOD) and coliform bacteria.

Estimation of BOD was done by oxygen determination by Winkler titration. Nitrate contents were analyzed with a HACH DR 4000 spectrometer. Measuring the EC and pH were conducted by EC meter (model CANT20) and pH meter (model R.T.CO) respectively. TDS was estimated by using oven-drying method. TH, Ca^{2+}, Mg^{2+} and Cl^{-} were estimated by titrimetry, Na^{+} and K^{+} by flame photometry. Estimation of Po_4^{3-} by molybdenum–blue complex formation using spectrophotometer (Systronic), while SO_4^{2-} were also determined by using either the same spectrophotometer.

For microbial test, nine tubes of lactose broth were prepared according to the size of the water sample i.e., 0.1, 1 and 10 mL respectively for all water samples. The test tubes are placed in incubator at 35ºC for 24 h for gas production. Production of gas confirms the presence of coliform in the sample. To confirm the presence of coliform, Eosin Methylen Blue agar (EMB) was used in which contains methylene blue that inhibits coliforms. The plates of Eosin Methylen Blue agar (EMB) are placed in incubator after streaking at 35°C for 24 h. E. coli colonies on this medium are small with metallic sheen. A single colony from EMB agar plate was picked up and inoculated it into lactose broth. The lactose broth was showed acid and gas production confirms the presence of coliform bacteria.

All physical and chemical tests were performed according to the Standard methods for the examination of water and wastewater (16).

Data Analysis: The effect of the leachate from Alborz landfill in Qom province (Qom, Iran) on quality of groundwater was investigated and findings were compared with Iran national drinking water standard.

Results

Analytical results of characteristics of groundwater samples from wells are presented in Table 2. The concentration of some contaminations in wells around the Albourz landfill are given and compared with Iran national drinking water standard in Fig. 1 to Fig 5.

Table 2) Physico-chemical and biological characteristics of groundwater

Well / Parameter	Ghomrod	Malek abad	Kashnian	Soltan baji	Gheshlagh	Mirab	Albourz 2	Albourz	Ganjineh	Mourab ganje
BOD(mg/l)	3.9	4.4	3.1	2.2	4.5	3.8	2.9	3.5	4.1	2.5
EC(μs/cm)	6300	9570	663	7680	14850	10620	2001	5940	3700	9830
TDS(mg/l)	3465	5263	3641	4224	8167	5841	1100	3267	2035	5406
pH	7.5	7.66	7.2	7.66	7.76	7.64	6.33	7.59	6.73	7.5
Na^+(mg/l)	38.92	73.64	61.23	59.84	112.1	82.11	58.40	45.22	33	69.74
K^+(mg/l)	12	29	28.8	18	37	25	18	9	12	21
Mg^2(mg/l)	5.4	15.7	17.4	9.5	20.11	16.7	14.6	11.1	12.8	16.5
Ca^{2+}(mg/l)	13.2	23.5	25	17.5	16.7	25.2	18.4	11.5	21	22.25
SO_4^{2-}(mg/l)	18.5	44.5	31.5	27.84	110.1	44.75	36.7	18.4	28.6	33.56
Cl^-(mg/l)	40.1	66.75	45.2	60.25	23.5	19.24	63.8	44.8	52.7	74.6
Po_4^{3-}(mg/l)	0.85	0.39	8.84	1.23	0.37	0.25	1.44	2.5	1.46	0.47
NO_3^-(mg/l)	23.8	22.5	32.8	31.5	24.5	22.8	28.7	31.6	34.12	21.3

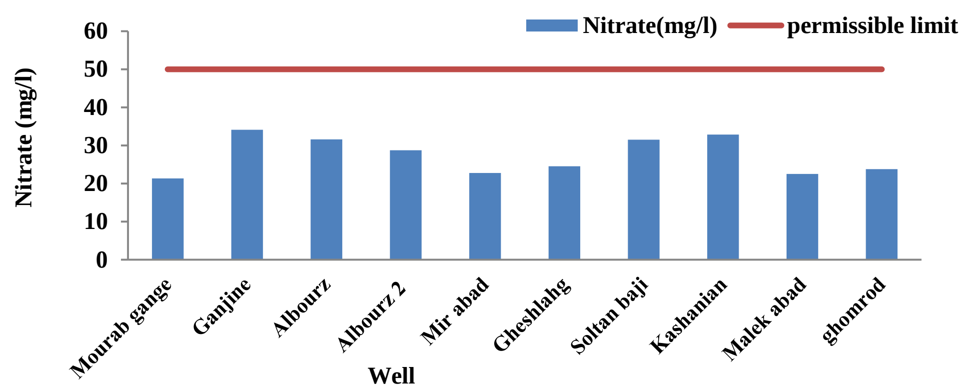

Figure 1) Concentrations of NO_3^- in groundwater samples and comparison with permissible limit of Iran national drinking water standard

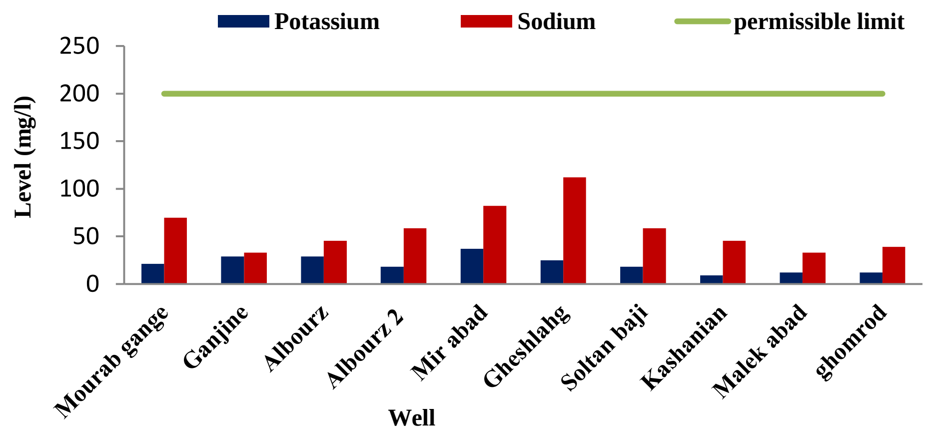

Figure 2) Concentrations of Na^+ and K^+ in groundwater samples and comparison with permissible limit of Iran national drinking water standard

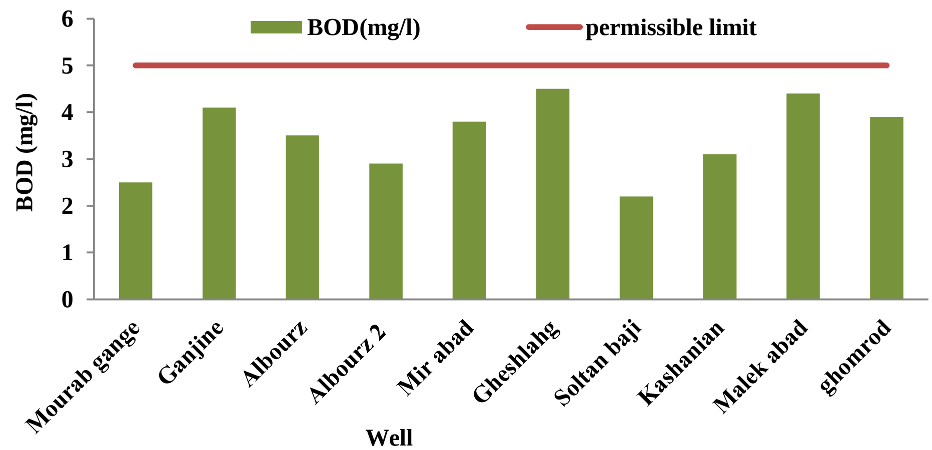

Figure 3) Concentrations of BOD in groundwater samples and comparison with permissible limit of Iran national drinking water standard

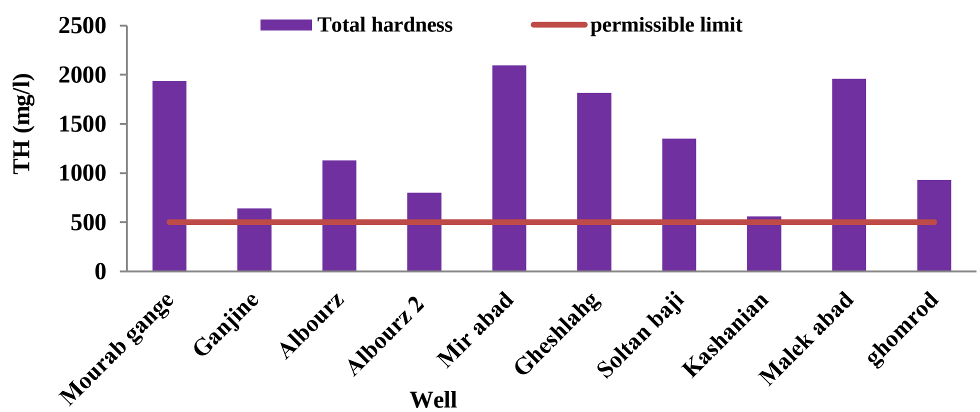

Figure 4) Concentrations of TH in groundwater samples and comparison with permissible limit of Iran national drinking water standard

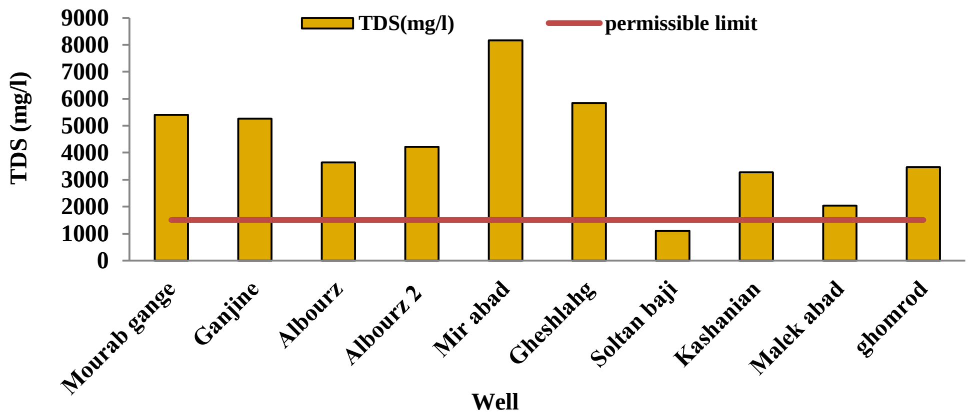

Figure 5) Concentrations of TDS in groundwater samples and comparison with permissible limit of Iran national drinking water standard

Discussion

Table 3 shows the desirable and maximum permissible limit recommended by Iran national drinking water standard.

According to The Fig.1, concentrations of NO_3^- in groundwater samples are between 21.3 mg/land 34.12 mg/l, Ganjineh recording the highest level. All reported values are below the Iran national drinking water standard. Results are confirmed with obtained findings by Mahvi and Rodbari in their study on 'The effect of landfill leachate of Shahrood city of Iran on groundwater quality" (18).

The pH of all the groundwater samples was about neutral. pH values for all samples are also shown in Table 2. The highest value of 7.76 is measured in Gheshlagh, whereas the lowest value of 6.33 is measured in Albourz. The results of pH for all wells, however, are in agreement with the range values of 6.5-9 determined by national standards (Table3).

The EC is a valuable indicator of the amount of material dissolved in water. The EC in the studied wells ranges between 663 and 14850 µS/cm in kashanian and gheshlagh respectively (Table 2).

In Malek Abad, Mourab Ganje, Albourz, Mirab, Gheshlagh, Soltanbaji, Ghomrod, obtained values are above the Iran national drinking water standard (Table 3).

Table 3) Desirable and maximum permissible limit recommended by Iran national drinking water

Parameter	Desirable level	Maximum permissible level
BOD(mg/l)	-	5
TDS(mg/l)	1000	1500
pH	6.5-8.5	6.5-9
Na^+(mg/l)	200	-
K^+(mg/l)	200	-
Mg^2(mg/l)	30	-
Ca^{2+}(mg/l)	300	-
SO_4^{2-}(mg/l)	250	400
Cl^-(mg/l)	250	400
NO_3^-(mg/l)	-	50
TH($caco_3$)	200	500

These high conductivity values obtained for the underground water near the landfill is an indication of its effect on the water quality. The same results were obtained by Mor et al. in their study on "Leachate characterization and assessment of groundwater pollution near municipal solid waste landfill site" (18).

The TDS concentration was found to be remarkably high at wells. The concentrations of Total Dissolved Solids (TDS) are different between wells. The highest content of 5840 mg/l is measured in Mirab, whereas, the lowest content of 1100 mg/l is measured in Albouraz 2 (Fig.5). This high value of TDS may be due to the leaching of various pollutants into the groundwater. Olaniya and Saxena also reported the groundwater pollution from refuse in the vicinity of the dumping sites detectable through increased TDS concentration of water (19). The high concentrations of TDS decrease the palatability and may cause gastro-intestinal irritation in human and may also have laxative effect particularly upon transits (20).

Multivalent cations, particularly Mg^{2+} and Ca^{2+} are often present in natural waters. These ions are easily precipitated and in particular react with soap to make it difficult to remove scum. Total hardness (TH) is normally expressed as the total concentration of Ca^{2+} and Mg^{2+} in mg/l, equivalent $CaCO_3$. The highest level of TH is recorded in Mir Abad in values of 2095 mg/l $CaCO_3$ (Fig.4). The TH in all samples is reported above recommended level.

The highest concentration of Ca^{2+} is measured in Malek Abad with the value of 23.5 mg/l, whereas the lowest Ca^{2+} concentration is measured in Albourz with the value of 11.5 mg/l. The excess of Ca^{2+} causes concretions in the body such as kidney or bladder stones and irritation in urinary passages (20). The levels of ca^{2+} in all samples are below the Iran national drinking water standard.

The concentration of Mg^{2+} ions varied from 5.4 to 20.11 mg/l in Ghomrod and Gheshlagh respectively (Table2). There is not any conflict in concentration of mg^{2+} with standard level.

The concentration of Na^{+} in water samples varied from 33 to 112 mg/l for Ganjineh and Gheshlagh respectively. The high concentration of Na^{+} may pose a risk to persons suffering from cardiac, renal and circulatory disease. The levels of Na^{+} in samples are lower than permissible limit (Fig.2). Raghimi et al. reported that the result of geochemical study of the groundwater samples in the landfill area indicates cations (Na^{+}, K^{+}, Mg^{2+}) and anions concentrations are more than Drinking Water Standards (21), and their results are conflict with the present study.

Sulphate (SO_4^{2-}) is detected in water wells at low concentrations. The highest amount of Sulphate could be observed in Gheshlagh well 110.1 mg/l. Sulphate levels in samples are below the allowable concentration. These values are in agreement with the range values obtained by Alsabhi et al. (22). High levels of sulphates could lead to dehydration and diarrhea and children are more sensitive to it than adults (20).

Phosphate(Po_4^{3-}) levels are in the range of 0.25 and 8.84 mg/1. In Kashanian, Albourz 2, Soltan Baji and Ganjineh Po_4^{3-} levels are significant and the highest level belongs to Kashanian. A trace of Po_4^{3-} even at 0.1 mg/l in water has deleterious effect on water quality by promoting the development of algal growth. Higher concentration is detrimental to food preparation because of its buffering effect (23). Phosphate, may be attributed to anthropogenic activity such as domestic and industrial waste discharge, leachate and agriculture related dumps etc (1). In the study that was investigated on "Groundwater quality assessment near a municipal landfill, Lagos, Nigeria", Longe and Balogun concluded the concentrations of Po_4^{3-} in groundwater are above the local standards (23).

Chloride concentration was measured, and ranges between 74.6 mg/l (Mourab Ganje) to 23.5 mg/l (Gheahlag). Chloride in reasonable concentration is not harmful, but it causes corrosion in concentrations above 250 mg/l, while about 400 mg/lit causes a salty taste in water (20). The source of chloride ions are related to ionic exchange between the rocks and percolated water while recharging the groundwater. The concentration values approach levels below the permitted limit (Table 3).

The concentration of BOD did not show different values between samples (Table 3). The greatest concentration content of 4.5 mg/ l is measured at Kashanian, whereas the lowest concentration content of 2.2 mg/l is measured at Gheshlagh. According to the Fig.3, the concentration of BOD is found below the allowable limit in drinking water. The results are in agreement with a study that has been done on "The effect of landfill leachate of Shahrood city of Iran on groundwater quality" by Mahvi and Rodbari (17).

Detecting of coliform bacteria is used to determine the faecal contamination. All of water samples to confirm the presence of coliforms were inoculated into lactose broth. The findings didn't reveal coliform presence in samples and all of them were reported negative. According to Iran national standards, nonentity of presence of coliform bacteria demonstrates the safe drinking water (Table 3).

It could be found from these results that there is little or no direct contamination of the groundwater by the leachate outflow. It is related to the soil stratigraphy of Albourz landfill that consists of clay intercalated with lateritic clay. This lithology is capable of protecting the underlying confined aquifer from leachate contamination. The subsurface geology of Albourz landfill site is similar to that of Solous landfill in Nigeria and thus suitable for an attenuation landfill if properly planned, designed and constructed (23).

Conclusion:

Results obtained in this study confirm that the quality of the groundwater resource underlying Albourz landfill hasn't been significantly impacted. The results of experiment of the following specific parameters Po_4^{3-}, TH and TDS are above the highest permissible levels allowed by Iran national Standards for Drinking Water. Presence of Po_4^{3-} in samples indicates a relation between domestic wastewater discharge and groundwater samples. TH and TDS don't cause to health problem in body but they could be disturbed for public welfare. The soil stratigraphy at Albourz landfill site consisting of clay and silt appears to have significantly influenced the low levels of contaminants found in groundwater samples. A particular attention should be paid to the wells of adjacent the Albourz landfill and in the direction of groundwater flow. The research recommends an upgrade of the Albourz landfill to a standard that would guarantee adequate protection of both the surface and the groundwater resources in the locality.

Footnotes

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Conflict of Interest:

The authors declare no conflict of interest.

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