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Assessment of the Physiochemical Characteristics of Water Samples from Vicinity Area of Wadafiae Landfill, Khartoum North, Sudan

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ABSTRACT: The rapid increase in population, urbanization, industrialization, and changes in consumption patterns have given rise to many environmental problems, which mainly include air, land, and water pollution. In Khartoum North, Khartoum State, Sudan, there was a lack of a compatible solid waste management system. These resulted in a decline in environmental health, and the majority of the yards were turned into dumps (kusha). The current study focused on the effects of uncontrolled dumping of municipal solid waste on groundwater, as well as assessing the risk of physiochemical concentrations in the water around the dumpsite and comparing the differences between the dry and rainy seasons in water samples at Wadafiea Dumpsite, Khartoum North, Sudan. Water parameters such as TSS, Cl, TDS, Ca, Mg, SAR, and Na exceeded the controlled 1 (1.333) and 2 (1.332) levels of water and was within the Sudanese Maximum Values, the bounds of Canadian Guideline Values, and WHO Values.

KEYWORDS: Water quality; physiochemical properties; Wadafiea dumpsite; landfill; Sudan.

1. Introduction

Solid waste is the garbage, refuse, sludge, and other discarded materials, including solid, liquid, semi-solid, or contained gaseous material, resulting from industrial, commercial, mining, and agricultural operations, as well as from community activities [1]. A huge amount of municipal solid waste (MSW) is produced on a daily basis since the generation rate is increasing even faster than the rate of urbanization [2]. The production of solid waste increased from 0.68 billion tons per year in 2000 to 1.3 billion tons per year in 2010. It is anticipated to reach 2.2 billion tons per year by 2025 and 4.2 billion tons per year by 2050 [2]. Municipal solid waste management plays a key role in achieving the United Nations Sustainable Development Goals (UNSDGs) related to livelihoods, poverty, public health, and environmental protection in low- and middle-income countries. Waste collection is a common phenomenon that can be found on the streets or in garbage dumps in several developing countries [3]. Water is essential to life on our planet, but it is becoming increasingly scarce and under threat. Clean water is essential for both nature and humans. Surface waters, on the other hand, are subjected to enormous pressures; estimates indicate that, in developing countries, surface waters may already be affected by severe pollution as a result of their easy accessibility for wastewater disposal or rains that release leachate in the surrounding environment from dumping sites and pose a risk to human health 2010 [4, 5]. Groundwater quality and quantity are major factors in the socio-economic development of a nation. Water quality is usually dynamic, subject to major changes with or without human interventions. Pollutants alter the physical, chemical, and biological characteristics of groundwater. Pollutants differ in their characteristics depending on their origin, the nature of the chemicals present in them, and the transformations that occur during their transport. The examination of groundwater quality basically refers to the determination of physio-chemical parameters, of which various organic and inorganic contaminants, especially metal pollutants, are of utmost significance. The physio-chemical environment of groundwater functions in many ways and influences the biotic components. It gives a picture of the environmental suitability of water for maintaining normal life. As a result, understanding the physio-chemical properties of groundwater is critical for proper utilization. Haphazard urbanization, industrialization, and improper disposal of solid wastes lead to the contamination of groundwater. The improper and unscientific solid waste dumps in unlined sewage drains drive pollutants into the groundwater regime, resulting in irreversible loss and the inability to restore groundwater quality to its original state. Improper management of municipal solid waste has serious effects on the quality of water, soil, plants, and people's lives. Municipal solid waste is typically dumped on open spaces in the majority of developing countries. Open dumps are the most common and easiest way of disposing of solid waste, and in the majority of cases they are located wherever land is available, without any concern about safety issues, health hazards, or aesthetic degradation.

2. Materials and Methods

2.1. Study area.

This study was carried out during the period between October 2019 to August 2020 in the landfill area and the surrounding area in the Wadafiea landfill located in the Eastern side of Kafoury, north of Haj Youssef and south of Napata area, Khartoum North (Bahri), Khartoum State. It is located between longitude 32°603363E and latitude 15°6762815N.

2.2. Laboratory tests.

2.2.1. Water samples collection.

Twenty water samples were collected from the Wadafiea dumping area and stored in 350-ml sterilized plastic bottles for physio-chemical analysis. The samples were collected in two seasons (the dry and rainy seasons). Water samples were collected from each season, and random sampling was adopted for the selected sampling points. Water samples were taken from the southern, western, and northern sides, as well as from a farm located on the northern side of the dumpsite. The samples were well labeled and transported to the laboratory of the Environmental and Natural Resources and Desertification Research Institute, Khartoum State, Sudan, and stored in the refrigerator at 4 °C until they were analyzed for physico-chemical parameters.

2.2.2. Determination of physico-chemical parameters of water.

Water analyses were carried out in accordance with the standard procedures outlined in the standard methods for water examination [6]. The refractive index (RI), electrical conductivity (EC), and hydrogen potential pH were measured using digital refractometers, an EC meter (Jenway - 4510), and a pH meter (WAP-CD 80 session - MM374). Application of the filtering method was used to determine the total dissolved solids (TDS) and total suspended solids (TSS) of water samples [7]. Chloride, carbonate and bicarbonate, the sodium adsorption ratio (SAR), calcium, magnesium, sodium, and potassium were all measured in water samples using the titrimetric method, and their concentrations were calculated using certain equations.

3. Results and Discussion

3.1. Refractive Index.

The physiochemical characteristics of the collected water samples revealed that the RI at 20 °C ranged from 1.335 in wells in southern B to 1.331 in wells in southeastern and western B during the dry season. The results of RI for water samples were compared to those of controlled samples. The RI of controlled 1 (1.333) was found to be the same as that of well A in the northern side and well A in the southern side, while the values of RI of well B in the western side and well in the southeastern (1.331) and well B (1.332) in the eastern side were below the controlled 1 limit values, with the exception of the readings of well B in the northern side and well A in the western and eastern sides and well B on the southern side exceeded the controlled 1 limit value, while controlled 2 (1.332) was found to be lower than the water sample result for RI at the channel near the dumpsite Table 1. Table 2 displays the results of RI at 20 °C for water samples collected during the rainy season, where the RI ranged from 1.332 in the channel, 1.333 in wells A and B on the northern side and in well A on the western side, 1.334 in well B on the western side, wells A and B on the eastern side, well A on the southeastern side, and well A on the southern side to 1.336 in well B on the southern side. The water samples were compared to controlled 1 and 2. The results showed that the water samples in the wells (northern A and B) and the channel (western A) were within the limits of controlled 1 (1.333) for wells and 2 (1.332) for channel, with the exception of the RI values of well B in the western side, well A and B in the eastern side, well in the southeastern side, and well A and B in the southern side being above controlled 1.

3.2. Total suspended solid (TSS).

TSS measurements for all water samples taken during the dry season ranged from 0.332 mg/l in well A at the dump site's northern side to 0.820 mg/l in well A at the eastern site. The TSS values of the water samples were compared to controls 1 and 2. The water samples of the channel surpassed the limit value of controlled 2 (0.568 mg/l), while the water samples of all the wells were higher than controlled 1 (0.348 mg/l), with the exception of the values of the TSS in the water samples of well A (0.332 mg/l) and well A (0.224 mg/l) on the northern and western sides, respectively, which were within the range levels of the controlled 1 (0.348 mg/l) shown in Table 1. Table 2 showed that, during the rainy season, the TSS in water samples were 1.980 mg/l in the channel, 0.362 mg/l and 0.418 mg/l in wells A and B at the northern side, 0.508 mg/l, 0.426 mg/l in wells A and B at the western side, 0.474 mg/l, 0.458 mg/l in wells A and B at the eastern side, 0.390 mg/l in the well at the south-eastern These readings demonstrated that the values of TSS in all water well samples were recorded at higher values than the controlled 1 (0.348 mg/l), while the value of TSS in the channel sample (1.980 mg/l) also exceeded the level value of the controlled 2. According to the aforementioned findings, the TSS values for the 20 water samples taken during the dry and rainy seasons were higher than the acceptable values for controls 1 and 2, and the TSS values in the water samples taken during the dry season were reported as having higher TSS findings than those taken during the rainy season. TSS was typically composed of fine clay or silt particles, plankton, organic compounds, inorganic compounds, and other microorganisms. These suspended particles range in size from 10 nm to 0.1 mm. Although, in standardized laboratory tests, TSS is defined as "the material that cannot pass through a 45-m-diameter flange." TSS as well as TDS can be influenced by changes in pH. Changes in the pH could cause some of the solutes to precipitate or affect the solubility of the suspended material. TSS was measured using the gravimetric method. These findings agreed with [8], who reported higher TSS in dry months than in wet months in Gombe, Nigeria. The highest value (0.40–0.45 mg/l) was recorded in the dry season, while the lowest value (0.36–0.38 mg/l) occurred in the wet season. This may be due to regular wastewater flow from nearby industries, human activities, and effluents from residences, markets, and restaurants. High TSS can lead to turbidity, which is an indication of pollution, and high TSS has been noted to be aesthetically unsatisfactory for baths and other domestic purposes [9].

3.3. Total dissolved solid (TDS).

Tables 1 and 2 showed that the range of TDS values in water samples during the dry and rainy seasons was 48.64 mg/l in a well on the southeastern side to 560.64 mg/l in well A on the eastern side during the dry season, while the TDS results in the rainy season ranged from 738.560 mg/l in well A on the northern side to 45.44 mg/l in well A on the eastern side. According to these readings, the TDS levels in water samples from wells A, B, and A on the northern and eastern sides during the dry season were above the limit levels of controlled 1 (51.84 mg/l), with the exception that the TDS levels for well B at the eastern side were below the acceptable limit values of controlled 1 (51.84 mg/l), while the TDS values in the channel at the northern side were above the limits of controlled 2. The results of TDS in well A (738.560 mg/l) at the northern side were above the controlled levels, although TDS values in water samples during the rainy season were found to be within the range levels of the controlled well 1 shown in Table 2. The TDS obtained values in all the sampling points were within the limit values of the Sudanese Maximum Limits [10], WHO [11] and Canadian Guideline Values [12] (1000 mg/l) and ($\leq$ 500 mg/l) respectively except the TDS values for well A (738 mg/l) at the northern side in the rainy season and well A (560.64 mg/l) at the eastern side in dry season exceeded the limit values of the Canadian Guideline ($\leq$ 500 mg/l). These results revealed that the TDS values in the dry season were higher than those in the rainy season. The possible reason for the variations might be due to the heavy rainfall that occurred during the rainy season. Intensive rainfall and percolation lead to more migration of leachate in the ground water samples and elevation in the ground water level, thus affecting the water quality in TDS. During the rainy season, a high TDS value leads to objectionable taste, odor, and color in the water. Our findings agreed with the findings of [13], which stated that high TDS values in groundwater near dumpsites were also reported by other studies on groundwater resources near waste dumpsites.

Table 1. Physicochemical characteristics of water samples near the dump area of solid waste at dry season.

Parameter	Channel	Well/ North A	Well/ North B	Well/ West A	Well/ west B	Well/ East A	Well/ East B	Well/ Southern East	Well/ South A	Well/ South B	Cont. (1) well	Cont. (2) channel	[a]Max. Value	[b]Canadian Value	[c]WHO Value
RI at 20 C°	1.333	1.333	1.334	1.334	1.331	1.334	1.332	1.331	1.333	1.335	1.333	1.332	-	-	-
TSS (mg/l)	0.696	0.332	0.420	0.224	0.460	0.820	0.800	0.456	0.452	0.558	0.348	0.568	-	-	-
TDS (mg/l)	54.40	67.84	356.48	55.04	49.28	560.64	49.92	48.64	49.28	49.92	51.84	51.20	1000	< 500	1000
pH	7.60	7.70	6.70	7.71	7.85	7.56	7.86	7.85	7.81	7.83	7.93	7.97	6.5 -8.5	6.5 -8.5	6.5 -8.5
SAR	0.215	0.214	0.272	0.211	0.201	0.310	0.231	0.232	0.201	0.246	0.195	0.181	-	-	-
Ca (mg/l)	2.767	2.288	11.721	2.470	2.389	17.976	2.713	2.434	2.288	2.436	1.555	1.536	200 ppm	-	150
Mg (mg/l)	2.783	2.938	3.176	2.840	2.785	3.083	2.808	2.607	2.639	2.021	2.100	2.507	150ppm	-	150
Na (mg/l)	2.112	2.059	4.035	2.020	1.896	5.385	2.261	2.152	1.866	2.024	0.632	0.878	250	≤ 200	200
K (mg/l)	0.851	0.831	1.266	1.263	0.977	0.517	0.614	0.375	0.826	0.566	0.085	0.087	-	-	-
CO_3- (meq/l)	ND	ND	ND	1.60	ND	1.60	0.800	0.800	ND	0.800	ND	1.200	-	-	-
HCO_3- (meq/l)	2.400	8.00	9.200	4.400	7.600	8.800	7.200	6.400	6.400	5.600	1.600	0.40	-	-	-
Cl^- (meq/l)	2.000	3.000	12.000	3.000	3.000	22.000	3.000	3.000	3.000	3.000	3.000	3.000	250	≤ 250	200-

ND: Not Detected; (-): Not Available; [a] Sudanese Maximum Value by SSMO, 2016; [b] Canadian Guideline Value, 2019; [c] WHO Guideline Value, 2018.

Table 2. Physicochemical Characteristics of Water Samples near the Dump Area of Solid Waste at Rainy Season.

Parameter	Channel	Well/ North A	Well/ North B	Well/ West A	Well/ west B	Well/ East A	Well/ East B	Well/ Southern East	Well/ South A	Well/ South B	Cont. (1) well	Cont. (2) channel	[a]Max. Value	[b]Canadian Value	[c]WHO Value
RI at 20 C°	1.332	1.333	1.333	1.333	1.334	1.334	1.334	1.334	1.334	1.336	1.333	1.332	-	-	-
TSS (mg/l)	1.980	0.362	0.418	0.508	0.426	0.474	0.458	0.390	0.512	0.500	0.348	0.568	-	-	-
TDS (mg/l)	53.120	738.560	46.08	46.08	46.08	45.44	46.72	52.48	51.20	50.56	51.84	51.20	1000	< 500	1000
pH	7.680	6.90	7.52	7.60	7.65	7.690	7.56	7.51	7.48	7.52	7.93	7.97	6.5 -8.5	6.5 -8.5	6.5 -8.5
SAR	0.260	0.940	0.240	0.245	0.234	0.239	0.225	0.261	0.183	0.251	0.195	0.181	-	-	-
Ca (mg/l)	2.871	18.333	2.943	2.759	2.602	2.557	2.560	3.296	2.020	2.945	1.555	1.536	200 ppm	-	150
Mg (mg/l)	4.020	6.653	5.376	4.253	4.240	3.793	4.550	5.489	4.750	4.740	2.100	2.507	150ppm	-	150
Na (mg/l)	2.073	5.357	1.532	1.571	1.443	1.617	1.269	1.798	1.292	1.697	0.632	0.878	250	≤ 200	200
K (mg/l)	0.613	0.196	0.122	0.169	0.103	0.168	0.103	0.163	0.115	0.148	0.085	0.087	-	-	-
CO_3- (meq/l)	1.200	0.80	1.200	ND	0.800	ND	ND	0.400	0.80	ND	ND	1.200	-	-	-
HCO_3- (meq/l)	0.600	3.40	0.200	0.400	0.800	1.000	1.800	1.800	0.80	1.800	1.600	0.40	-	-	-
Cl^- (meq/l)	1.000	25.00	3.000	2.00	2.000	3.000	3.000	2.000	3.000	3.000	3.000	3.000	250	≤ 250	200-

ND: Not Detected; (-): Not Available; [a] Sudanese Maximum Value by SSMO, 2016; [b] Canadian Guideline Value, 2019; [c] WHO Guideline Value, 2018

3.4. pH level.

pH is classified as one of the most important water quality parameters. The measurement of pH relates to the acidity or alkalinity of the water. A sample is acidic if the pH is below 7.0. Meanwhile, it is alkaline if the pH is higher than 7.0. Acidic water can lead to the corrosion of metal pipes and plumbing systems. Meanwhile, alkaline water promotes disinfection in water. The normal drinking water pH range mentioned in Sudanese, Canadian guideline values, and WHO guidelines is between 6.5 and 8.5. The levels of the pH of the water samples in the dry and rainy seasons are presented in Tables 1 and 2. According to the study's findings, the levels of pH varied from 6.70 in well B on the northern side to 7.86 in well B on the eastern side, respectively, during the dry season (Table 1). While in the rainy season, the pH values ranged from 6.90 in well A on the northern side to 7.690 in well A on the astern side (Table 2). The pH values for all water samples were slightly alkaline, with the exception of wells B and A on the northern side in the dry and rainy seasons, which were slightly acidic (6.70 and 6.90, respectively). During the dry and rainy seasons, all of the water samples were slightly acidic and alkaline, but within Sudanese, Canadian, and WHO guidelines and below the controlled 1 of 7.93 for wells and controlled 2 of 7.97 for channels. The current pH values were comparable to those obtained by [14] in dam water samples from Ekiti, Nigeria, and by [15] in Itaogbolu, Ondo-State, Nigeria.

3.5. The SAR.

The values of SAR were mentioned in Tables 1 and 2 for the dry and rainy seasons, respectively. The findings of the SAR values in the dry season were between 0.201 and 0.183 in wells B and A on the western and southern sides, respectively, during the dry season (Table 1), while in the rainy season they ranged from 0.940 in well A on the northern side to 0.183 in well A on the southern side (Table 2). The SAR values of all water samples from wells were above the limit value of control 1 (0.195) in both seasons, except that the value in well A at the southern side in the rainy season was below the limit value of control 1 (0.195), while the SAR values in channels exceeded the range value of control 2 (0.181) in both the dry and rainy seasons.

3.6. The calcium and magnesium.

Tables 1 and 2 provide explanations of the concentrations of calcium (Ca) and magnesium (Mg) during the dry and rainy seasons, respectively. According to Table 1, the concentration of calcium in water samples ranged from 17.976 mg/l in the eastern A to 2.288 mg/l in the northern and southern A sides, while during the rainy season it varied from 18.333 mg/l in the northern A to 2.020 mg/l in the southern A (Table 2). These findings confirmed that the concentration record values of Ca during the dry and rainy seasons were greater than those observed in controlled 1 (1.555 mg/l) and 2 (1.536 mg/l), respectively, while remaining within the permitted ranges of Sudanese and WHO guideline values. The results showed that the values for both seasons fluctuated between high and low values, but wells (northern B) (11.721 mg/l) and well A (17.976 mg/l) on the eastern side in the dry season and well A (18.333 mg/l) in the rainy season on the northern side were found to have high concentrations of calcium. These high values of this pollutant in wells were caused by their proximity to the dump site.

The majority of the waste disposed of and generated at dump sites was due to the fact that food, which always contains The concentration of Mg in water samples varied from a minimum of 2.021 mg/l (well B at the southern side) to a maximum of 3.176 mg/l (well B at the northern side) during the dry season, and from a minimum of 3.793 mg/l (well A at the eastern side) to a maximum of 6.653 mg/l (well A at the northern side) during the rainy season. The readings of Mg concentration for wells and channel water samples in the dry and rainy seasons were higher than controlled 1 (2.100 mg/l) and controlled 2 (2.507 mg/l) for both wells and channel water samples, respectively, while all findings of Mg concentration in water samples were within Sudanese Maximum Values and WHO Guideline Values, which were found to be similar (150 ppm) for both standards. The Mg concentration values in water samples from wells and channels were higher in the rainy season than in the dry season.

3.7. The sodium and potassium.

Tables 1 and 2 show the concentration values for Na and K in water samples collected during the dry and rainy seasons, respectively. In the dry season, the concentration of Na ranged from a minimum of 1.866 mg/l (well A on the southern side) to a maximum of 5.385 mg/l (well A on the eastern side), while in the rainy season, the concentration values ranged from a low of 1.269 mg/l (well B on the eastern side) to a high of 5.357 mg/l (well A on the northern side). These findings demonstrated that sodium Na levels in every well water sample and channel were above the limits of controlled 1 (0.632 mg/l) and controlled 2 (0.878 mg/l), respectively, during the dry and rainy seasons, and that every water sample during both seasons fell within the acceptable limits of Sudanese, Canadian, and WHO Guideline Values (250 mg/l), (200 mg/l), and (200 mg/l), respectively. K levels in water samples ranged from 0.375 mg/l (well on the southeastern side) to 1.266 mg/l (well B on the northern side) during the dry season, and from 0.103 mg/l (well B on both the western and eastern sides) to 0.613 mg/l (channel) during the rainy season. According to the results of our study, the concentration of K level in all water samples from wells and channels was higher than in control 1 (0.085 mg/l) and control 2 (0.087 mg/l), respectively. The concentrations of Na and K in wells and channels were found to be higher during the dry season when compared to the rainy season, possibly due to the dilution process of the contaminating ions by rain. A previous study in India confirmed these findings and noted that other analyzed parameters, such as TDS, TH, Ca^2, Mg, Na, K, Cl^-, CO_3^{2-}, HCO^-_3, NO^-_3, and SO^{2-}_4 were found to have greater concentrations in the leachate collected during the dry season as compared to the wet season leachate sample, which clearly indicates the influence of landfill leachate on the groundwater and surface water [21].

3.8. The carbonate, bicarbonate, and chloride ions.

The results regarding CO_3^-, HCO_3^- and Cl^- in water samples near the dump site are presented for the dry and rainy seasons in Tables 1 and 2, respectively. The obtained results in the water sample revealed that the concentration values of CO 3 in the dry season were not detected in any water sample or in the controlled 1 except in wells A on the western and eastern sides, which were found to be 1.60 meq/l and 0.800 meq/l in wells B on the eastern and southern sides, respectively, and in the well on the southeastern side, and in the well on the southeastern side. The value of CO_3^- in the channel was compared to the controlled 2 for the channel, which was found to be 1.200 meq/l, and the results showed that the value of CO_3^- in the channel was similar to the controlled 2. In the dry season, bicarbonate HCO_3^- concentrations in water samples near the dumpsite ranged from a minimum of 2.40 meq/l in a channel to a maximum of 9.20 meq/l in a well B on the northern side, while during the rainy season, concentrations ranged from 0.200 meq/l in a well B on the northern side to 3.40 meq/l in a well A on the northern side. During the dry season, all water samples exceeded the controlled 1 (1.600 meq/l) value for wells and the controlled 2 (0.40 meq/l) value for channels, whereas during the rainy season, the results fluctuated between low and high concentration levels, with the channel result exceeding the controlled 2 (0.40 meq/l). The values of HCO_3^- concentration during the dry season period were higher than during the rainy season, which might be due to the rainfall, which diluted the concentrations of HCO_3^-. The concentration of chloride ions Cl^- in the water samples ranged from 22.00 in well A on the eastern side to 2.00 in the channel during the dry season. Results showed that the concentration of Cl^- in wells and channel water samples were below or similar to the limits of controlled 1 (3.00) and controlled 2, respectively, with the exception of the results of wells B (12.00) and well A (22.00) at the northern and eastern sides, which were above the value of controlled 1. During the rainy season, the chloride ion concentration in the water samples ranged from 1.00 in the channel to 25.00 in well A on the northern side. The findings indicated that the concentration values of Cl^- in all samples of water for both seasons were within the limit values of Sudanese, Canadian, and WHO guideline values (250, 250, and 200–300). In our study, the concentration values of Cl^- in the water sample collected in the study area indicated that the level values of Cl^- in the dry season were higher than the rainy season, and the results of those higher values were in line with the findings of [16] in India, which explained that the chloride values of the groundwater samples ranged from 78 to 1100 and 50 to 998 mg/l collected during the dry and wet seasons, respectively. Chloride in reasonable concentrations, chloride is not harmful, but it may cause corrosion at concentrations above 250 mg/l; at about 400 mg/l, it can cause a salty taste in water. An excess of chloride in water is usually taken as an index of pollution and considered a tracer for groundwater contamination [17]. The high levels indicated pollution from landfill waste, which requires treatment before use [18]. These results of our study disagreed with [19–23], in which the authors explained that the levels of chlorides were statistically significantly higher than those of prior measurements conducted in other developing countries.

4. Conclusions

Dumping of solid wastes into the Wadafiea landfill without proper lining or leachate collection systems may be a potential source of water contamination and an increased concentration level for physiochemical parameters. Unsegregated waste contains many components that alter the quality of groundwater through leachate migration. In our study, the concentration values of physiochemical parameters of water samples in the dry season were higher than those in the rainy season. Water parameters such as TSS, Cl^-, TDS, Ca, Mg, SAR, and Na exceeded the controlled 1 and 2 levels of water and were within the Sudanese Maximum Values, the bounds of Canadian Guideline Values, and WHO Values. In the future, it may lead to several health problems for the population that consumes it. Hence, we can conclude from our study that the dumping of unsegregated waste in a landfill may lead to severe deleterious effects on the quality of underground water, wells, and canals. The separation of waste is a must before dumping it on land. Hence, it is highly recommended that monitoring of the groundwater resources at and around the Wadafiea dumpsite be carried out. Strict waste segregation schemes should be adopted. A proper landfill should be used to dump waste that would limit the entry of leachate and pollutants into the ground, thus reducing the pollution of groundwater resources.

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Competing Interest

The authors declare that there are no conflicts of interest.

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