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The Characteristics of Leachate and Groundwater Pollution at Municipal Solid Waste Landfill of Ibb City, Yemen

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Abstract: Problem statement: Yemen one of the developing country suffering from water pollution. Landfill is one of the source of water pollution. There are several boreholes located close to Ibb landfill used for drinking water. A study of composition of landfill leachate and groundwater pollution was conducted at Ibb landfill, which is located at Al-Sahool area, north of Ibb City, Yemen. **Approach:** The leachate was sampled at three different locations of the landfill, at the landfill itself and 15 and 20 m downstream of this landfill. Groundwater samples collected from 5 boreholes to study possible impact of leachate percolation into groundwater. Leachate and groundwater samples were collected during dry season only, due to the excessive generation of leachate during this season. Objective of this study was significant to assess degree of groundwater pollution due to Ibb landfill leachate at Al-Sahool area. The leachate and groundwater were physically and chemically characterized by using spectrophotometer HACH, BOD Trak HACH, flame photometer (PFP 7) and Inductively Coupled Plasma of Optical Emission Spectrometry (ICP-OES) model Vista MPX. Parameters measured were pH, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Dissolved Oxygen (DO), Fluoride (F), Chloride (Cl), Sulphate (SO_4), Nitrites (NO_2), Nitrates (NO_3), ammonia-N (NH_3-N), heavy metals (Pb, Zn, Ni, Cr, Cd, Cu), major cations (Na, Mg, Ca, K, Fe) and biological parameters (COD, BOD_5 and coliform group bacteria). **Results:** The results showed that, leachate at landfill most likely in methanogenic phase, based on the alkaline pH value recorded (pH = 8.46). The results also showed that 4 out of 5 boreholes were contaminated, where concentration of physico-chemical parameters are above the standard acceptable levels which required for drinking water adapted by Yemen's ministry of water and environment and by word standard. **Conclusion:** Therefore, landfill is dangerous for environment so government should do sanitary landfill to prevent further contamination to surface water, groundwater as well as soil.

Key words: Ibb landfill, groundwater, pollution, heavy metals

INTRODUCTION

Pollution occurs when a product added to our natural environment adversely affects nature's ability to dispose it off. A pollutant is something which adversely interferes with health, comfort, property or environment of the people. Generally, most pollutants are introduced in the environment as sewage, waste, accidental discharge and as compounds used to protect plants and animals. There are many types of pollution such as air pollution, soil pollution, water pollution, nuclear pollution and oil pollution[1].

Open dumps are the oldest and the most common way of disposing of solid waste and although in recent years thousands have been closed, many still are being used. In many cases, they are located wherever land is available, without regard to safety, health hazard and aesthetic degradation. The waste is often piled as high as equipment allows. In some instances, the refuse is ignited and allowed to burn. In others, the refuse is periodically leveled and compacted. As a general rule, open dumps tend to create a nuisance by being unsightly, breeding pests, creating a health hazard, polluting the air and sometimes polluting groundwater and surface water[2].

Landfill is an engineered waste disposal site facility with specific pollution control technologies

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designed to minimize potential impacts. Landfills are usually either placed above ground or contained within quarries, pits. Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse[3].

Municipal solid waste did not pose a significant problem until humans established settlements. Prior to that time, the types and quantities of waste were readily degraded or consumed by animals or naturally degraded without causing significant impact to the environment[4].

Leachate pollution is the result of a mass transfer process. Waste entering the landfill reactor undergoes biological, chemical and physical transformations which are controlled, among other influencing factors, by water input fluxes. In the reactor three physical phases are present: The solid phase (waste), the liquid phase (leachate) and the gas phase. The liquid phase is enriched by solubilized or suspended organic matter and inorganic ions from the solid phase. In the gas phase mainly carbon (prevalently in the form of CO_2 and CH_4) is present. The main environmental aspects of landfill leachate are the impacts on surface water quality and groundwater quality if leachate is discharging into these water bodies[5].

The leachate corresponds to atmospheric water that has percolated through waste, interacting with bacteriological activity and especially organic substances. Its composition is a function of the nature and the age of the landfill, the type of wastes, the method of burying, the geological nature of the site, the climate[6].

Groundwater is that portion of subsurface water which occupies the part of the ground that is fully saturated and flows into a hole under pressure greater than atmospheric pressure. Groundwater occurs in geological formations known as aquifer. An aquifer (gravel/sand) may be defined as a geologic formation that contains sufficient permeable materials to yield significant quantities of water to wells and springs; this implies an ability to store and transmit water[7].

Groundwater is an important source of drinking water for humankind. It contains over 90% of the fresh water resources and is an important reserve of good quality water. Groundwater, like any other water resource, is not just of public health and economic value; it also has an important ecological function[8].

The objective of this study is to assess the groundwater pollution due to Ibb landfill at Al-Sahool area. Leachate consists of high concentrations of physico chemical which can pollute groundwater and soil.

MATERIALS AND METHODS

Ibb city (Fig. 1) is located between Sana'a, the capital of Yemen and Taiz governorates. It is about 193 km from Sana'a. It is about 5383 km^2. Ibb city is located at latitude 13º58′48″and longitude 44º10′48″ Ibb landfill is located in Al Sahool area with an area of 0.8 km^2. It is an open dump. It is a fertile agricultural area and there are plantations surrounding the site,

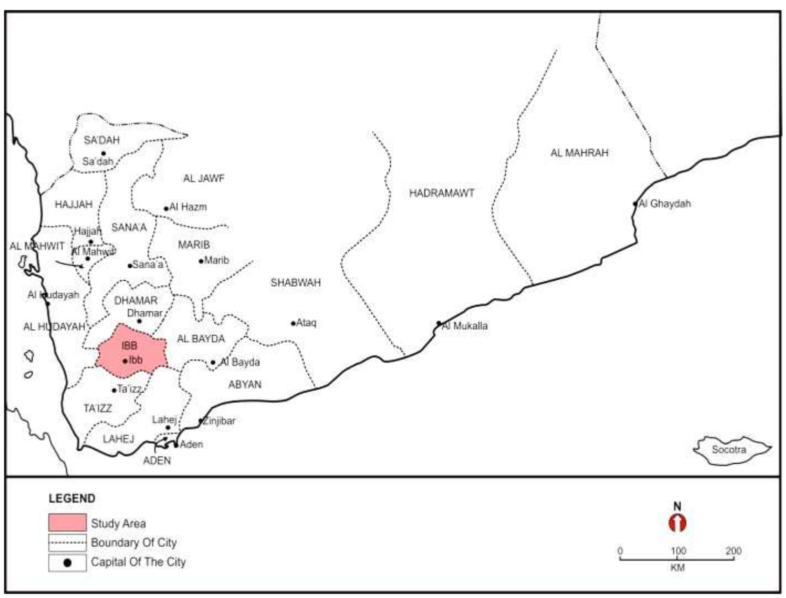

Fig. 1: Location of Ibb city

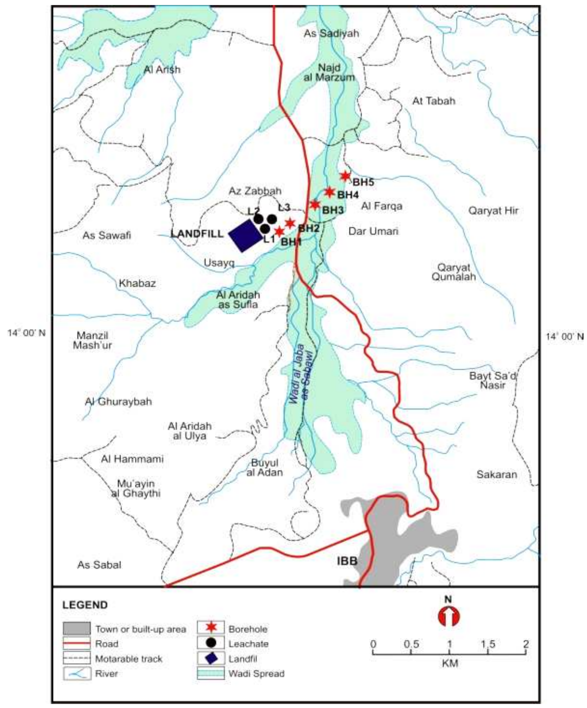

Fig. 2: Location of leachate and boreholes

such as quality corn and coffee plantations to the south of the site. There is an expected variety in wildlife, especially with reptiles.

There are some cows, sheep and donkeys in the area, which have been raised by the local farmers. Some of these animals were actually inside the dump site. With the growth of the population in this governorate, the wastes of different kinds have also increased. They are dumped near the residential areas.

Leachate samples were collected from Ibb landfill which is located in Al-Sahool area. Three different sites of leachate were selected. The first leachate sampling point is very close to the landfill, whereas another two sampling points are about 15 m and 20 m respectively from landfill. Groundwater samples were also collected from five boreholes (Fig. 2). Glass bottles were used to collect leachate and groundwater samples for chemical analyses, whereas, samples preserved for BOD_5 and COD tests were collected in polyethylene bottles covered with aluminum foils. A few drops of concentrated nitric acid were added to all the water samples collected for heavy metals analysis to make the pH equal 2.0. The samples were then transported in a cool box to be stored under suitable temperature until analysis.

Chloride was measured by the Mercuric Nitrate Titrimetric Method. Calcium and hardness were measured by the EDTA titrimetric methods.

Magnesium was measured by calculation as the difference between total hardness and calcium hardness as follows:

$$\text{Total hardness (as } CaCO_3) = 2.497\ [Ca^{2+},\ mg\ L^{-1}] + 4.118\ [Mg^{2+},\ mgL^{-1}]$$

Then:

$$4.118\ [Mg^{2+},\ mgL^{-1}] = \text{Total hardness (as } CaCO_3) - 2.497\ [Ca^{2+},\ mgL^{-1}]$$

Where:

Ca hardness = Ca ion×2.5

Mg hardness = Mg ion×4.11

The laboratory of Ibb Water and Sanitation Local Corporation (IWSLC) was used for analyzing of water samples. Spectrophotometer HACH (DR 4000 models 48000 and 48100) was used for measuring of PO_4, SO_4, NO_3, NO_2, F and NH_3. Flame photometer (PFP 7) was used to determine Sodium (Na) and Potassium (K). The Yemen Standardization Metrology and Water Quality control Organization in Sana'a were used for preparing and analyzing of heavy metals by using Inductively Coupled Plasma of Optical Emission Spectrometry (ICP-OES) model Vista MPX. NO_3, NO_2, F and NH_3. Flame photometer (PFP 7) was used to determine Sodium (Na) and Potassium (K). The Yemen Standardization Metrology and Water Quality control Organization in Sana'a were used for preparing and analyzing of heavy metals by using Inductively Coupled Plasma of Optical Emission Spectrometry (ICP-OES) model Vista MPX.

Nine tubes of lactose broth (Fig. 3) 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. (Table 3) shows the Most Probable Number (MPN) of coliforms. 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 containsmethylene blue that inhibits coliforms. The plates of Eosin Methylen Blue agar (EMB) is 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 a cid and gas production confirms the presence of coliform bacteria.

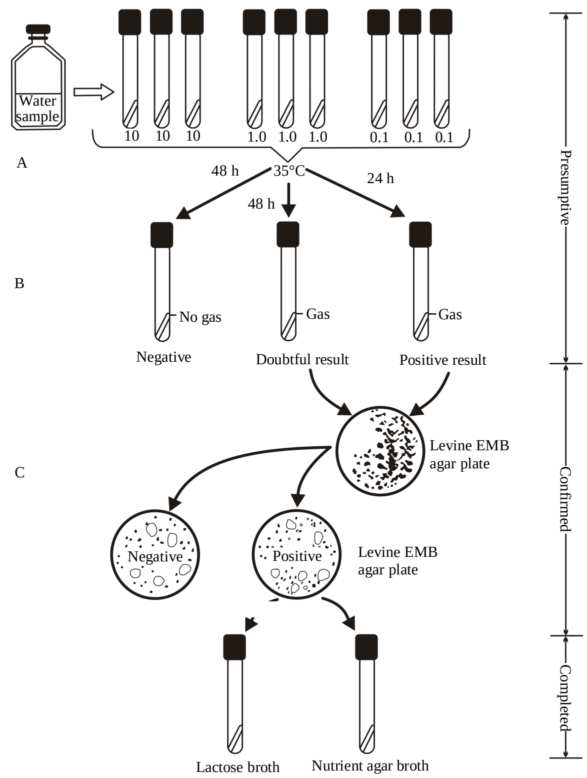

Fig. 3: Bacteriological analysis of water for coliform bacteria

RESULTS

The results of the measured insitu parameters including pH, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) are shown in (Table 1). The pH values for all three leachates are 8.46, 8.45 and 8.42 respectively in which first site is located very close to the landfill and another two sites are located approximately 15m and 20m distance from Ibb landfill.

pH values for all boreholes are also shown in (Table 1). The highest value of 8.16 is measured in BH5, whereas the lowest value of 7.27 is measured in BH1. The temperature values of three leachates show the same values as it is influenced by air temperature. The temperature measurements are approximately the same between the boreholes.

Electrical Conductively (EC) values show variety results between three leachates. The highest value is obtained at the first site with the value of 49800 µS cm^{-1}, whereas the lowest value is obtained at the third site with the value of 49600 µS cm^{-1}. These values are higher than the values obtained by[6,9,11-13]. However the EC values which are obtained for the three leachates are not within the standard range of 0.7 to 4 µS cm^{-1} required for treated wastewater discharge determined by[15]. Conductivity is used as an indicator of the abundance of dissolved inorganic species or total concentration of ions[12].

Electrical Conductivity (EC) values show very different results between the boreholes. The highest value is in BH1 (5120 µS cm^{-1}), whereas the lowest value recorded in BH5 (650 µS cm^{-1}).

The concentrations of Total Dissolved Solids (TDS) between three leachates showed different values. The greatest concentration content of 32370 mg L^{-1} is measured at the first site, whereas the lowest concentration content of 32240 mg L^{-1} is measured at the third site.

The concentrations of Total Dissolved Solids (TDS) are different between boreholes. The highest content of 3328 mg L^{-1} is measured in BH1, whereas, the lowest content of 422.5 mg L^{-1} is measured in BH5.

The Dissolved Oxygen (DO) values of the leachate show approximately the same values. These results are in agreement with the range of values 0.12-3.20 mg L^{-1} obtained by[14]. Dissolved Oxygen (DO) measurements showed different values for all boreholes. The highest concentration of 4.1 mg L^{-1} is measured in BH4 whereas the lowest concentration of 2.2 mg L^{-1} is measured in BH1.

The concentration of BOD_5 did not show different values between three leachates (Table 3). The greatest concentration content of 2060 mg L^{-1} is measured at the first site, whereas the lowest concentration content of 2000 mg L^{-1} is measured at the third site. The COD values of the three leachates showed different values. The highest value of 19880 mg L^{-1} is measured at the first landfill leachate, whereas, the lowest value of 19840 mg L^{-1} is measured at the third landfill leachate.

These include fluoride (F^-), chloride (Cl^-), sulfate (SO_4^{-2}), nitrites (NO_2^-), nitrates (NO_3^-) and ammonia-N (NH_3-N). The results are shown in Table 4. The highest concentration value of $F^-$is measured in BH1 with the value of 5.67 mg L^{-1}, whereas the lowest concentration measured in BH5 with the value of 0.51 mg L^{-1}. The concentrations of sulfate at the three leachates are 336.0, 294.7 and 253.3 mg L^{-1} respectively.

The concentrations of SO_4 between the boreholes are different. The highest concentration of SO_4 is measured in BH1 with the value of 72 mg L^{-1}, whereas the lowest concentration is measured in BH5 with the value of 26.7 mg L^{-1}. The NO_2 levels in groundwater are varied. The highest level is recorded in BH1 with the value of 0.65 mg L^{-1}, whereas the lowest level is recorded in BH5 with the value of 0.015 mg L^{-1}.

Table 1: Insitu parameters of leachate and groundwater

Parameter	pH	T	EC (µS cm^{-1})	DO (mg L^{-1})	TDS (mg L^{-1})
Leachate 1	8.46	23.7	49800.0	0.2	32370.00
Leachate 2	8.45	23.7	49700.0	0.1	32305.00
Leachate 3	8.42	23.6	49600.0	0.1	32240.00
BH1	7.27	25.5	5120.0	2.2	3328.00
BH2	7.30	26.5	3000.0	2.3	1950.00
BH3	7.77	26.1	1243.0	3.3	807.95
BH4	7.90	25.0	823.0	4.1	534.95
BH5	8.16	25.2	650.0	3.5	422.50

Table 2: pH, EC and biological parameters in different leachates in different

Parameters	Christensen *et al*[3].	Ehrig[10]	Amina *et al.*[6]	Saleh *et al*[11]	Banar *et al*[12]	Yoshida *et al.*[13]
pH	4.5-9	5.3-8.5	8.3-8.8	4.05-8.87	6-9	6.67-7.69
EC (µS $cm^{-}1$)	2500-35000	-	26.0	7.0-31.0	2.01-34.2	10-44.5
BOD_5 (mg $L^{-}1$)	20-57000	100-90000	60-311	5.00-400	111-3044	1-.0-7.0
COD (mg $L^{-}1$)	140-152000	150-10000	1000-1900	23.00-460	209-4148	8.0-29.0
BOD_5/COD (mg $L^{-}1$)	0.02-0.08		0.06-0.16	-	-	0.123-0.463

Table 3: BOD_5, COD and BOD_5/COD at Ibb landfill leachate

Parameters	Leachate 1	Leachate 2	Leachate 3
BOD_5 (mg L^{-1})	2060.00	2030.00	2000.00
COD (mg $L^{-}1$)	19880.00	19860.00	19840.00
BOD_5/COD (mg L^{-1})	0.01	0.01	0.01

Table 4: Concentration of major anions and nitrogenous compounds

Parameter	F^-(mg L^{-1})	Cl^-(mg L^{-1})	SO_4^{-2} (mg L^{-1})	NO_2^-(mg L^{-1})	NO_3^-(mg L^{-1})	NH_3-N (mg L^{-1})
Leachate1	135.000	3905.00	336.00	11.000	1500.00	1379.160
Leachate2	119.200	3727.50	294.70	11.000	1000.00	1199.600
Leachate3	103.300	3550.00	253.30	11.000	1000.00	1020.000
BH1	5.670	3161.63	72.00	0.650	50.00	3.570
BH2	0.840	1423.60	47.80	0.072	16.67	1.450
BH3	0.565	350.00	33.80	0.026	24.00	0.129
BH4	0.660	134.90	32.11	0.025	11.67	0.010
BH5	0.510	85.20	26.70	0.015	7.00	0.010

Table 5: Anions and nitrogenous compounds in different leachate

Parameters	Christensen *et al.*[3]	Ehrig[1]	Abdulatif[15]	Amina *et al.*[6]
F^-(mg L^{-1})	-	0.015-0.86	0-0.3	-
Cl^-(mg L^{-1})	150-4500	30.0-4000	6.06-983.12	5680
SO_4^{-2} (mg L^{-1})	8-7750	10.0-1200	3.57-8.37	1150
NO_2^-(mg L^{-1})	-	0.0-25	0.02-0.70	-
NO_3^-(mg L^{-1})	-	0.1-50	1.38-1.67	290
NH_3-N (mg L^{-1})	50-2200	1-1500	-	105

The concentrations of ammonia NH_3-N for all boreholes gave different values. The highest concentration of ammonia is detected in BH1 with the value of 3.57 mg L^{-1}, whereas lowest concentration of ammonia is detected in BH5.

The major cations include Fe, Na, K, Ca and Mg is shown in (Table 6). The distribution of Fe at the three leachates shows different values. The highest Fe content of 46.0 mg L^{-1} is measured at the first leachate sample, whereas the lowest content value of 45.7 mg L^{-1} is measured at the third leachate sample. The concentration of Ca at the three leachates site showed different values. The highest concentration is measured at the first leachate site with the value of 1840 mg L^{-1}, whereas the lowest concentration of Ca is recorded at the third leachate site with the value of 960 mg L^{-1}. Mg concentrations for the three leachates site show different values. The highest Mg content value of 288 mg L^{-1} is measured at the first leachate site, whereas the lowest Mg content value of 136 mg L^{-1} is measured at the third leachate site. The highest concentration of Ca is measured in BH1 with the value of 669.2 mg L^{-1}, whereas the lowest Ca concentration is measured in BH5 with the value of 76 mg L^{-1}. The content values of Mg measured in the boreholes are varied. The highest content value is measured in BH1 with the value of 225.12 mg L^{-1},

Table 6: Concentration of major cations at leachate

Parameter	Fe (mg L^{-1})	Na (mg L^{-1})	K (mg L^{-1})	Ca (mg L^{-1})	Mg (mg L^{-1})
Leachate 1	46.000	6300.0	4900.00	1840.0	288.00
Leachate 2	45.900	6200.0	4800.00	1400.0	212.00
Leachate 3	45.700	6200.0	4800.00	960.0	136.00
BH1	1.250	64.0	2.00	669.2	225.12
BH2	0.066	56.0	1.67	352.0	108.00
BH3	0.117	32.5	1.25	124.4	47.27
BH4	0.054	20.0	1.10	96.0	35.04
BH5	0.010	20.0	1.00	76.0	31.80

whereas the lowest content value is measured in BH5 with the value of 31.8 mg L^{-1}. The high concentration of hardness is reported in BH1 with the value of 2611 mg L^{-1} followed by BH2 with the value of 1330 mg L^{-1}, whereas the lowest concentration is reported in BH5 with the value of 300 mg L^{-1}.

The heavy metals include lead (Pb), zinc (Zn), nickel (Ni), chromium (Cr), cadmium (Cd) and copper (Cu). The concentrations of heavy metals are shown in Table 9. The highest concentrations of heavy metals are recorded at the first leachate site. Cu concentration is the highest concentration of heavy metals with the value of 21.5 mg L^{-1}, whereas the lowest concentration of heavy metals is recorded for Cr with the value of 0.14 mg L^{-1}. The concentration of Pb is the highest at the first leachate site, whereas the lowest concentration of Pb was in the third leachate site. The high concentration of Ni is found in BH1 with the value of 0.165 mg L^{-1}, whereas the lowest concentration of Ni is found in BH5 with the value of 0.065 mg L^{-1}. The concentrations of Cu in all boreholes are different. The highest concentration of Cu is recorded in BH1 with the value of 9.611 mg L^{-1}, whereas the lowest concentration of Cu is recorded in BH5 with the value of 0.126 mg L^{-1}.

DISCUSSION

These results of pH are in agreement with the range values obtained by[6,9-12] (Table 2). In contrast, these results are higher than the values obtained by[13]. The pH of the leachate depends not only on the concentration of the acids that are present but also on the partial pressure of the CO2 in the landfill gas that is in contact with the leachate[12]. These results indicate that the three leachates are at the later stages of methanogenic phase. This means that, the age of Ibb landfill, rainfall and kind of waste are the most important factors which affect the composition of leachate. However, the pH values obtained at the three leachate samples are not within the standard range of 6.5-8.4 required for treated wastewater discharge for irrigation determined by local standard.

The results of pH for all boreholes, however, are in agreement with the range values of 6.5-9 determined by local standards. These results are also in agreement with the range values of 6.5-9.5 determined by local standard which is required for drinking water. No health based guideline value is proposed for pH. Although pH usually has no direct impact on consumers, it is one of the most important operational water quality parameters. If the pH is above 7, this will indicate that water is probably hard and contains calcium and magnesium[17].

The values of EC for leachate are higher than the values obtained by[6,9,11-13]. However the EC values which are obtained for the three leachates are not within the standard range of 0.7 to 4 µS cm^{-1} required for treated wastewater discharge determined by local standard. Conductivity is used as an indicator of the abundance of dissolved inorganic species or total concentration of ions[12].

The high values of EC in BH1, BH2 and BH3 are not within the range values of 450-1000 µS cm^{-1} determined by local standards which is required for drinking water. On the other hand, EC values in BH4 and BH5 are within the Yemen standard value which is required for drinking water. The high values of EC in BH1, BH2 and BH3 are due to the effect of the leachate seepage into these boreholes. Conductivity was used to give an idea of the amount of dissolved chemicals in water and the presence of Na, K and Cl. The elevated values of EC in the first three boreholes suggested that there is inorganic pollution compared to the last two boreholes. Conductivity is not a problem in itself and just because it is above certain level does not mean that the water will cause illness[14].

The results of TDS for leachate are high compared to the range of 1625-22750 mg L^{-1} values obtained by[9] and also high compared to the range of 3.70-18.0 mg L^{-1} obtained by[11]. These results of the three leachates are higher than the standard range of 450-3000 mg L^{-1} required for treated wastewater discharge determined by local standard.

TDS concentrations in BH1 and BH2 are not within the standard acceptable levels of drinking water determined by local standards. On the contrary, the TDS concentrations in BH3, BH4 and BH5 are in agreement with the local standards and international standards. The high value of TDS in BH1and BH2 can be attributed to the affect of the leachate seepage from Ibb landfill, which contains high concentration of dissolved salts of 32370 mg L^{-1} to the groundwater. The anaerobic microbial activities within the three leachate sites could be the reasons of reducing DO in leachate. The lowest concentration of DO in BH1and BH2 indicate that the affect of these boreholes by the migration of leachate from the body of the landfill. They also indicate that this borehole is rich with organic matter where bacteria has used the oxygen to biodegrade it. It has been assumed that these pollutants are transported from leachate and most likely will be transported to the groundwater and pollute it.

The values of BOD_5 for leachate are greater than the values obtained by[6,11-13]. On the other hand, these results are in agreement with the values obtained by[9] and also in agreement with the values obtained by[10]. These BOD_5 results for the three sites are higher than the standard values required for treated wastewater discharge determined by local standard.

The results of COD for leachate are greater than the range values obtained by[6,11,13]. On the other hand, these results are in agreement with the range of 140-45000 mg L^{-1} values obtained by[9] and with the range of 150-100000 mg L^{-1} values obtained by[10]. The changes in leachate biodegradability are mainly reflected by theBOD_5/COD ratio. The BOD_5/COD ratio tends to decrease as the age of leachate increases, varying from 0.5 for a relatively “fresh” leachate to 0.2 for an older (more stabilized) one. In mature landfills, the BOD_5/COD ratio is often in the range of 0.05-0.2. The ratio drops because leachate from mature landfills typically contains humic and fulvic acids, which are not readily biodegradable Owing to their biodegradable nature, organic compounds, which contribute to COD, decrease more rapidly than inorganic ones with increasing age of leachate. Therefore, the observed decrease in BOD_5/COD ratio represents a more complete oxidation of organic carbon, corresponding to higher (positive) oxidation conditions[12]. In this study, the BOD_5/COD ratio is 0.1 mg L^{-1}. This result is high compared to the range values obtained by[9]. On the contrary, this result is in agreement with the range values which obtained by[6,13]. This means that the composition of leachate depends on the kind of waste and age of the landfill. In general, BOD_5 and COD contents for the three leachates exceeded the standard limit of 150 and 500 mg L^{-1} respectively for the treated wastewater discharge determined by[14]. Therefore, the leachate can be identified a mature landfill and not fresh leachate.

The F^-concentrations and Cl concentrations measured at the three leachates are greater than the values (Table 5) obtained by[14,17]. In contrast, these values are lower than the results obtained by[6]. On the other hand, these results in agreement with the range values obtained by[9,10]. In general, the F and Cl concentrations for the three leachates samples exceeded the standard limit of 1 and 4-10 mg L^{-1}, respectively for the limits of treated wastewater discharge determined by local standard.

The F^-concentration in BH1 is high compared to the standard acceptable levels of drinking water determined by local and international standards. On the contrary, F^-concentrations in the other four boreholes are in agreement with the standard acceptable levels of drinking water determined by local standards and international standards. This means that, BH1 is the most affected boreholes by the leachate migration from the landfill. The concentrations of Cl^-between boreholes were different. The highest concentration of $Cl^-$is reported in BH 1 with the value of 3161.63 mg L^{-1}, whereas the lowest concentration of $Cl^-$is reported in BH5 with the value of 85.2 mg L^{-1}. The Cl^- concentrations in BH1, BH2 and BH3 are higher than the standard acceptable levels of drinking water determined local standards and international standards.

On the other hand, the Cl^-concentrations in BH1 and BH2 are higher than the Cl^-concentrations (1188.48 mg L^{-1}) obtained by[14]. The high chloride ion usually provides early indication of the presence of leachate in the groundwater[19]. This means that, leachate is presented in BH1, BH2 and BH3.

The results of SO_4 for leachate show high values compared to the values reported by[14,19]. On contrary, these results are low compared to the result obtained by[6]. On the other hand, these values are in agreement with the range values obtained by[9,10]. This means that, there are several factors which can effect the composition of leachate such as the age of landfill, kind of waste and physical, chemical, biological process. The concentrations of SO_4 in groundwater in this study are very low and did not pose any significant water quality problem, because these results are within the standard acceptable levels of drinking water determined by local standards and international standards.

The concentration of nitrogenous compounds indicates the occurrence of extensive anaerobic bacterial activities. The concentration of ammonia NH_3 for the first site of leachate is 1379.16 mg L^{-1} and the third leachate site of 1020 mg L^{-1} show high values compared to the values reported by[6,14]. On the other hand, these values are in agreement with the range values obtained by[9,10] Table 5.

According to[17], ammonium ion (NH_4) is transformed into ammonia (NH_3) based on pH through the following reaction:

$$NH_4 \longrightarrow NH_3 + H^+$$

or

$$NH_4OH \longrightarrow NH_3 + H_2O$$

On the other hand, nitrite is oxidized into nitrate which can be quickly assimilated by plants or otherwise reduced again to nitrite and NH_3. So the concentrations of nitrate for the three leachates are higher than the ranges values (0.2-10.3 mg L^{-1}) obtained by[1].

The NO_2 level in BH1 is high compared to the standard acceptable levels of drinking water determined by local standards and international standards. The reason may be due to the migration of leachate from the body of Ibb landfill. On the other hand, the NO_2 levels in the other boreholes are very low and did not show any significant water quality problem.

The NO_3 levels in the boreholes are very low and did not pose any significant water quality problem. Nitrate is reduced to nitrite in the stomach of infants and nitrite is able to oxidize haemoglobin (Hb) to methaemoglobin (metHb), which is unable to transport oxygen around the body. Guideline value for combined nitrate plus nitrite should not exceed 1[16]. In this study the combined of nitrate plus nitrite did not exceed 1. The high concentration of NH_3-N in BH1 and BH2 can be attributed to the leachate seepage from Ibb landfill.

The values of major cations for leachate, which are reported at the three leachates, are found in a good agreement with most results obtained by[1,9,10]. On the contrary, these results are high compared to the results obtained by[13,14]. On the other hand, the results of 0.37-8.08 mg L^{-1} obtained by[12] are low compared to the results in this study. These values, however, are higher than the standard values which are required for the treated wastewater discharge determined by the local standard.

Among all the cations analysed, Na showed high concentration levels in the landfill leachate. The highest concentration of Na is measured at the first leachate site with 6300 mg L^{-1}, whereas the lowest concentration is recorded at the third leachate site with 6200 mg L^{-1}. This Na concentration in the landfill leachate lies within the typical normal range of municipal leachate[1,9,13]. In contrast, these values are higher than the values recorded by[10,14] and higher than the standard values which are required for the standard acceptable levels of treated wastewater discharge determined by[14].

The distribution of K at the three leachates site showed different values. These values are higher than the values which were recorded by[1,9,10,13,14] (Table 7). Ca concentration at the three leachates site lies within the typical normal range of municipal leachate[1,9-11,13]. On the contrary, Ca concentration (190 mg L^{-1}) which obtained by[6,14] is high compared to the Ca concentration in this study.

This Mg concentration for the three leachates lies within the typical normal range of municipal leachate[1,9,10,13] and within the range (93-7000 mg L^{-1}) which obtained by[11]. The distribution of major cations in Ibb landfill leachate can be attributed to the influence of the waste composition.

The distribution of Na and K in all boreholes did not pose any significant water quality problem, because these cations are within the standard acceptable levels of drinking water determined by local standards and international standards. The concentrations of Fe in all boreholes are varied. The highest concentration is found in BH1 with the value of 1.25 mg L^{-1}, whereas the lowest concentration is found in BH5 with the value of 0.01 mg L^{-1}. This result is high compared to the results (0.021-0.024 mg L^{-1}) obtained by[6]. The high concentration of Fe in BH1 is not within the standard acceptable levels of drinking water determined by local standards and international standards. This means that, this borehole is affected by the migration of leachate from the body of the landfill. On the contrary, Fe concentrations in BH2, BH3, BH4 and BH5 are within the standard acceptable levels of drinking water determined by local standards and international standards.

Among all the cations analyzed, Ca show high concentrations level in all boreholes. The high concentration of Ca in BH1, BH2, BH3 and BH4 are not within the standard acceptable levels of drinking water determined by local and international standards.

Table 7: Concentration of cations in different leachate

Parameters	Christensen *et al*.[9]	Ehrig[10]	Misra[1]	Yoshida *et al*.[13]
Fe (mg L^{-1})	3-5500	0.4-2200	0.0-2820	0.026-0.076
Na (mg L^{-1})	70-7700	50.0-4000	0.0-7700	2575.850-3676.90
K (mg L^{-1})	50-3700	10.0-2500	28.0-3700	33.284-265.49
Ca (mg L^{-1})	10-7200	10.0-2500	50.0-7200	700.530-2037.70
Mg (mg L^{1})	30-15000	50.0-115	17.0-15600	213.490-2089.40

Table 8: Levels of water and type of water

Water type	Equivalent $CaCO_3$
Soft	<60-75
Slightly hard	75-150
Hard	150-300
Very hard	>300-350

This means that, BH1, BH2, BH3 and BH4 are affected by the migration of Ibb landfill leachate from the waste.

The high contents of Mg in BH1, BH2, BH3 and BH4 are not within the standard acceptable levels of drinking water determined by local and international standards. This means that, BH1, BH2, BH3 and BH4 are affected by the migration of Ibb landfill leachate from the waste via soil to the groundwater.

There are two types of water hardness, temporary and permanent. Temporary hardness is removed when the water is boiled this is the process that leaves deposits of calcium carbonate on water heaters and kettles. Permanent hardness is formed as the cations pass over rocks containing sulphate ions[14]. Table 8 shows the levels of hardness of water and the type of water. This means that water in BH1, BH2, BH3 and BH4 is very hard. Water in BH5 is hard. BH1, BH2, BH3 are the most effected boreholes by leachate seepage from the body of the landfill.

The results of Pb for leachate are higher than the results obtained by[10,13,14] and with the result (0.006 mg L^{-1}) obtained by[6] (Table 10).On the contrary, these results are in agreement with the range results obtained by[9]. On the other hand, these results lie within the standard acceptable levels of treated wastewater discharge determined by local standard.

The concentrations of Pb all boreholes are high compared to the result (0.001 mg L^{-1}) which obtained by[17] and also high compared to the result (0.006 mg L^{-1}) which obtained by[6]. On the other hand, these results are higher than the standard acceptable levels of drinking water determined by local standards and international standards. Pb has been known to be toxic to human. The effect of Pb on the mental development of children causes the most concern. It has been calculated that lead can cause a reduction of between 5-15% of a child's intelligence depending on the amount found in the water[17]. This indicates that, all boreholes are contaminated by Pb and affected by the migration of leachate to the groundwater.

Zn concentrations for three leachate sites are higher than the results obtained by[6,12-14]. On the contrary, these results are in agreement with the range results obtained by[9,10]. On the other hand, these results are not within the standard acceptable levels of treated wastewater discharge determine by local standard.

Ni and Cr concentrations for three leachate sites are in agreement with the range results obtained by[9, 10]. On the other hand, these results are not within the standard acceptable levels of treated wastewater discharge determined by local standard. This means that, the composition of the waste consist of the Ni and Cr compounds.

The high concentrations of Ni in all boreholes are not within the standard acceptable levels of drinking water determined by local standards and international standards. The reason may be due to the high concentration of Ni in leachate which migrates to the groundwater via soil.

The concentration of Zn and Cr in all boreholes did not pose any significant water quality problems, because these concentrations are below the standard acceptable levels of drinking water determined by local standards and international standards.

The Cd content is present in Ibb landfill leachate. This means that, the waste of the landfill consists of the Cd compounds. On the other hand, the boreholes around the are affected by these compounds in which these boreholes contain high concentration of Cd compared to the standard acceptable levels of drinking water determined by[15,16]. Also these results are high compared to the result (0.0005 mg L^{-1}) which obtained by[6].

The concentrations of Cu in Ibb landfill leachate show the same values. These results are higher than the results obtained by[6,9,10,12-14]. On the contrary, these results are not within the standard acceptable levels of treated wastewater discharge determined by local standard. The results (0.021-0.024 mg L^{-1}) which obtained by[6] are low compared to the results in this study. The high concentration of Cu in BH1, BH2, BH3 and BH4 are not within the standard acceptable levels of drinking water determined by local standard and international standard. The reason may be due to the effect of these boreholes by the migration of leachate to the groundwater.

The results of microbiological analysis are shown in Table 11. The results show that three different leachate contains coliform group bacteria**.** Escherichia coli are the most widely adopted indicator of faecal pollution and they can also be isolated and identified fairly simply, with their numbers usually being given in the form of faecal coliforms (FC)/100 mL of wastewater.

Table 9: Concentration of heavy metals

Parameter	Pb (mg L^{-1})	Zn (mg L^{-1})	Ni (mg L^{-1})	Cr (mg L^{-1})	Cd (mg L^{-1})	Cu (mg L^{-1})
Leachate 1	2.850	85.500	1.800	0.155	0.3000	21.500
Leachate 2	2.750	57.000	1.750	0.150	0.2500	21.500
Leachate 3	2.600	56.000	1.700	0.145	0.3000	21.500
BH1	0.283	2.550	0.165	0.010	0.1890	9.611
BH2	0.241	0.115	0.023	0.004	0.1800	5.340
BH3	0.225	0.092	0.026	0.012	0.1530	1.053
BH4	0.223	0.085	0.040	0.007	0.1180	0.107
BH5	0.142	0.192	0.065	0.001	0.0095	0.126

Table 10: Concentration of heavy metals in different leachate

Parameters	Ehrig[10]	Chistensen *et al*.[3]	Yoshida *et al*.[13]	Banar *et al*.[12]	Amina *et al*.[6]
Pb (mg L^{-1})	0.0008-1.02	0.0010-5	0.01-0.18	0.00-0.065	-
Zn (mg L^{-1})	0.0500-170	0.0300-1000	0.03-0.80	0.04-0.59	0-0.7472
Ni (mg L^{-1})	0.0200-2.05	0.0150-13	0.13-0.67	0.19-0.95	0-0.1338
Cr (mg L^{-1})	0.0300-1.6	0.0200-1.5	0.14-1.80	0.00	0.00-0.15633
Cd (mg L^{-1})	0.0005-0.14	0.0001-0.4	0.01-0.03	0.00-0.06	0-0.034
Cu (mg L^{-1})	0.0040-1.4	0.0050-10	0.04-0.09	0.00-5.63	0-0.159

Table 11: Microbiological results of leachate and boreholes

Parameter	3 of 10 m each	3 of 1 m each	3 of 0.1 m each	MPN index 100 m^{-1}
Leachate 1	3	3	3	2400
Leachate 2	3	3	3	2400
Leachate 3	3	3	3	2400
BH1	3	3	3	2400
BH2	3	3	3	2400
BH3	0	2	3	93
BH4	0	0	1	3
BH5	0	0	0	0

Escherichia coli are indicator organisms that are widely used to detect faecal contamination of water and the assumption is that if faecal coliform bacteria are present in a sample, then human pathogenic bacteria could also exist Pathogenic organisms give rise to the greatest health concern in agricultural use of wastewaters, yet few epidemiological studies have established definitive adverse health impacts attributable to the practice Coliforms and Faecal Coliforms. The Coliform group of bacteria comprises mainly species of the genera Citrobacter, Enterobacter, Escherichia and Klebsiella and includes Faecal Coliforms, of which Escherichia coli is the predominant species[17].

CONCLUSION

Leachate from Ibb landfill is most likely in methanogenic phase in which pH was 8.46. The BOD_5/COD ratios (0.1 mg L^{-1}) indicate that the three different leachates are partially old and stable. The first site of landfill leachate is characterized by the highest concentration parameters. Most of parameters in Ibb landfill leachate exceeded the permissible limit required for treated wastewater discharge determined by local standard. The concentration of heavy metals in Ibb landfill leachate is above the standard acceptable levels of treated wastewater discharge determined by the local standard. The concentration of Pb lies below the permissible limit of 0.2 mg L^{-1}, which is required for treated wastewater discharge determined by local standard. The concentrations of Pb, Ni, Cu, Cd, Cl, Ca, Mg, NH_3, hardness and Total Dissolved Solid (TDS) are the highest in BH1. BH2 is contaminated by Pb, Cu, Cd, Cl, Ca, Mg, NH_3 and hardness, BH3 is contaminated by Pb, Ni, Cu, Cd, Cl, Ca, Mg and hardness whereas, BH4 is contaminated with Pb, Ni, Cu, Cd, Ca, Mg and hardness. The present of *E. coli* in BH1, BH2 and BH3 indicate that, these boreholes are contaminated by coliform group bacteria. These boreholes are affected by the migration of leachate from the body of the landfill to the groundwater. The high concentrations of the pollutants in the leachate reach and contaminate the groundwater. Therefore, urgency for leachate treatment at this site is recommended to prevent further contamination to surface and groundwater.

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