A Study of Surface Water and Groundwater Pollution in Ibb City, Yemen

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ABSTRACT

A study was carried out to determine the land use impact on water pollution at three different sites i.e Al-Sahool, Mitm and Al-Sayyadah valleys around Ibb city, Yemen. Besides determining the status of water pollution, this study also aims to recognize the sources of pollution and the results will be used to identify the relationship between the impact of land use activities and water pollution. Groundwater samples were collected in all valleys. While leachate samples were collected only from Al-Sahool area and surface water samples from Mitm area. Groundwater was sampled from the existing wells that were drilled in these areas. Surface water and leachate were sampled from small stream and leachate ponds. The physico-chemical characteristic of leachate, groundwater and surface water samples such as pH, temperature, electrical conductivity (EC), total dissolved solids (TDS), dissolved oxygen (DO) were measured in-situ, while fluoride (F), chloride (Cl), sulphate (SO4), nitrites (NO2), nitrates (NO3), ammonia-N (NH3-N), heavy metals (Pb, Zn, Ni, Cr, Cd, Cu), major cations (Na, Mg, Ca, K, Fe) and biological parameters (COD, BOD5) were analysed in the laboratory. The results show that, the leachate from the landfill is in methanogenic phase. The BOD5/COD value of 0.1 mg/l obtained for leachate suggested the partially stabilization. For the groundwater at Al-Sahool area borehole two is the most contaminated borehole, in which physico-chemical parameters are higher, followed by borehole three, borehole four and borehole five. At Mitm area the surface water in general seems to be affected by the discharge of untreated wastewater based on the comparison with unpolluted surface water outside the area. The groundwater quality at Mitm area shows that, only three boreholes are contaminated due to the percolation of untreated wastewater. For Al-Sayyadah area, the low values of physico-chemical parameters indicate a clean area and this is due to the absence of sources of contaminations. In general, Al-Sahool area is the most contaminated area compared to Mitm and Al-Sayyadah areas. The contamination level at Mitm area is higher than Al-Sayyadah area due to the discharge of wastewater directly to the Mitm valley. Therefore, a leachate collection pond should be build to collect and treat the leachate to prevent further contamination as well as build more sanitary landfill facilities in Al-Sahool area to prevent further contamination. An additional wastewater treatment plant at Mitm area is highly recommended to prevent further contamination to surface and groundwater.

KEYWORDS: surface water, leachate, groundwater, pollution, heavy metals.

INTRODUCTION

In developing countries only a small proportion of the wastewater produced by sewered communities is treated. Developing country governments and their regulatory agencies, as well as local authorities (which may be city or town councils, or specific wastewater treatment authorities, or more generally water and sewerage authorities), need to understand that domestic and other wastewaters require treatment before discharge or, preferably, re-use in agriculture and/or aquaculture (Duncan, 2003). Municipal wastewater effluents may contain a number of toxic elements, including heavy metals, because under practical conditions wastes from many small and informal industrial sites are directly discharged into the common sewer system. These toxic elements are normally present in small amounts and, hence, they are called trace elements. Some of them may be removed during the treatment process but others will persist and could present phytotoxic problems. Thus, municipal wastewater effluents should be checked for trace element toxicity hazards, particularly when trace element contamination is suspected (Pescod, 1992). Open dumps are the oldest and the most common way of disposing of solid wastes, and although in recent years thousands have been closed, many are still 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 was ignited and allowed to burn. In others, the refuse was 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 (Keller, 1982). Landfill is an engineered waste disposal site facility with specific pollution control technologies designed to minimize potential impacts. Landfills are usually either placed above ground or contained within quarries, pits etc. Landfills are sources of groundwater and soil pollution due to the production of leachate and its migration through refuse (Chistensen & Stegmann, 1992). 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. 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 (Armon & Kott, 1994).

MATERIALS AND METHODS

Three different sites of leachate collection points were selected in and around Ibb landfill for monitoring of the groundwater quality. The first leachate sampling point is very close to the landfill, whereas another two sampling points are about 15m and 20m respectively from the landfill. Groundwater samples were also collected from five boreholes as shown in Figure 1. Groundwater samples were collected from five boreholes at Mitm area. Surface water samples were also collected from three different sites, the upstream, the middle, and the downstream of Mitm valley (Figure 2). Groundwater samples were collected from seven boreholes from agricultural area Al-Sayyadah area. The boreholes are distributed in different locations around the city Figure 3. 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 preserve the samples. The samples were then transported in a cool box to be stored under suitable temperature until analysis.

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. BOD Trak HACH was used for determining the BOD_5. Flame photometer (PFP 7) was used to determine Sodium (Na) and Potassium (K). The Yemen Standardization Meteorology and Water Quality control Organization in Sana'a were used for preparing and analyzing the heavy metals via Inductively Coupled Plasma of Optical Emission Spectrometry (ICP-OES) model Vista MPX.

Chloride was measured by the Mercuric Nitrate Titrimetric Method, whereas, Calcium was measured by the EDTA titrimetric methods. The hardness was measured by the EDTA titrimetric methods.

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

Total hardness (as $CaCO_3$) = 2.497 [Ca^{2+}, mg/L] + 4.118 [Mg^{2+}, mg/L].

Then 4.118 [Mg^{2+}, mg/L] = Total hardness (as $CaCO_3$) - 2.497 [Ca^{2+}, mg/L]

Where
Ca hardness = Ca ion × 2.5
Mg hardness = Mg ion× 4.11

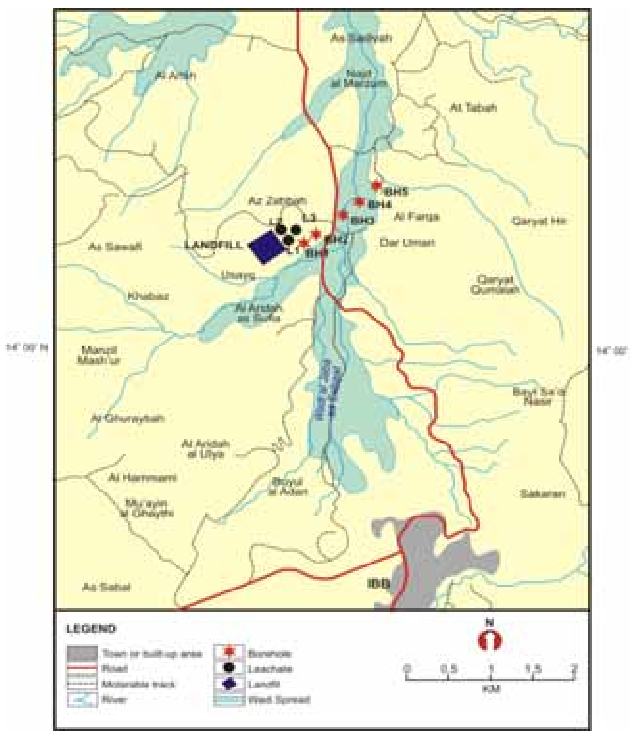

Figure 1: Location of leachate and boreholes at Al-Sahool area

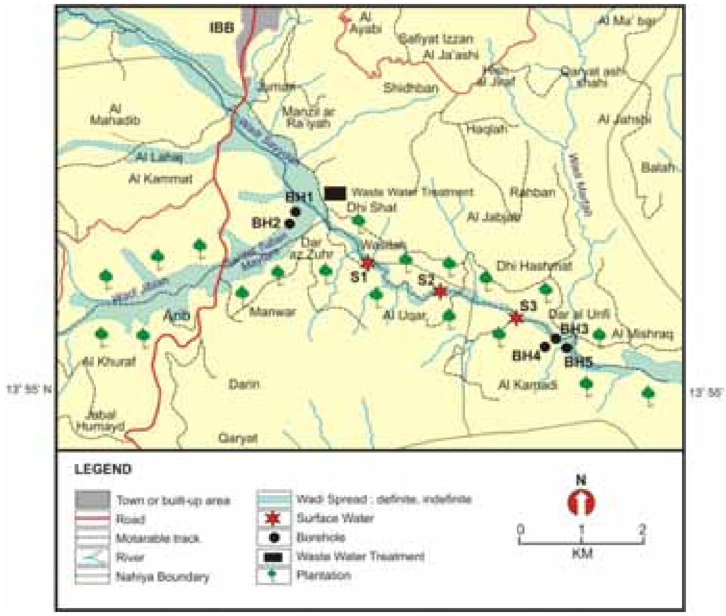

Figure 2: locations of groundwater and surface water samples at Mitm area

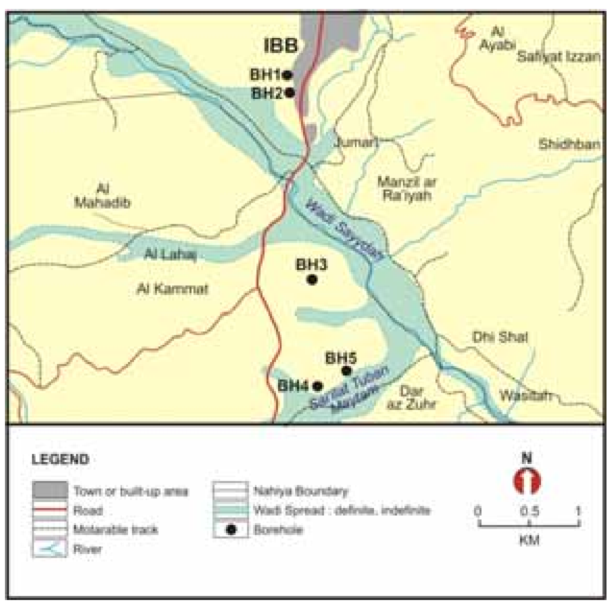

Figure 3: Location of boreholes in Al-Sayyadah area

RESULTS AND DISCUSIONS

Physico-chemical parameters of leachate and surface water

The pH values of the three leachate collected samples were found to be 8.02, 8.00 and 7.99 respectively. There is a general consensus that the lower pH cluster represents the acid producing phase and the upper cluster represents the methanogenic phase (Alloway 1995). During the initial stage the pH values are quite low, while during the methanogenic stage the pH appeared to be neutral to alkaline (Fatta et al. 1998).

The pH values of all surface water sampling site was alkaline in which the range being 8.10-8.28. The highest value of 8.28 was measured at the downstream site, whereas the lowest value of 8.10 was measured at the upstream site. These results were high if compared to the result of unpolluted surface water which is 6.87. pH usually has no direct impact on consumers. The normal pH range for irrigation water is from 6.5 to 8.4. pH values outside this range are a good warning that the water is abnormal in quality (Pescod 1992). Electrical Conductivity (EC) values show different values between the three leachates in which higher average values of 4993 µS/cm is obtained in the first leachate sample, whereas the lower average values of 4942 µS/cm is obtained in the third leachate sample. These values are not within the standard range of 0.7 to 4 µS/cm set by (YMWE 1999). The highest electrical conductivity (EC) was obtained at the upstream site with the value of 2105 µS/cm, whereas the lowest value was obtained at the downstream site with the value of 2022.22 µS/cm. These results were high if compared to the result of unpolluted surface water which is 568.6 µS/cm. These results are also high compared to the standard acceptable levels 0.7 to 4 µS/cm of irrigation purpose determined by Yemen's Ministry of Water and Environment (YMWE 1999). The concentration of total dissolved solids (TDS) fluctuated widely among the examined leachates. The greatest concentration content of 3246 mg/l is measured in the first leachate sample whereas the lowest concentration of TDS is measured in the third leachate sample with the value of 3212 mg/l. The concentrations of total dissolved solids (TDS) were different between the three surface waters. The maximum value of 1368.83 mg/l was measured at the upstream station, whereas the minimum value of 1314.3 mg/l was measured at the downstream station. These results were high if compared to the result of unpolluted surface water which is 369.42 mg/l.

The dissolved oxygen (DO) values for all leachates demonstrate very close values. The anaerobic microbial activities within this landfill could be the preferable reason caused by the depletion of DO. This assumption has been asserted by results obtained by Townsend et al. (2004) who confirmed that in landfill leachate, highly reducing conditions and low DO concentrations are typically found because of anaerobic microbial activity. The dissolved oxygen (DO) values of the surface water show approximately different values. These results were high if compared to the result of unpolluted surface water which is 13.4 mg/l. Oxygen becomes dissolved in surface waters by diffusion from the atmosphere and from aquatic-plant photosynthesis. Dissolved oxygen is consumed by the degradation (oxidation) of organic matter in water. The leachate maturity indicator includes BOD_5 and COD. The distribution of BOD_5 fluctuated widely in that the first leachate site has recorded the greatest content of 1110 mg/l, whereas the lowest content of 1083 mg/l was measured at the second and the third site respectively. Similarly, the greatest COD content value was measured at the first leachate site with the value of 10530 mg/l, whereas the lowest content value of 10507 mg/l was measured at the third leachate site. These values are generally within the normal range of typical municipal landfill leachate which are reported by (Ehrig 1989 & Christensen et al. 2002). The high values of these indicators suggested the instability of microbial activity at the first leachate site and the presence of high BOD_5 and COD indicates the high organic strength. The BOD_5 /COD ratios of 0.1 mg/l which were calculated for all leachate correspond to partially stabilization of these leachates. This ratio is supported by the results of many researchers such as Amina, (2004), Baha'a (2005) and Yoshida et al. (2002). According to Curi et al. (1994) who found in their study that, the ratio of BOD_5 /COD between 0.4 mg/l to 0.6 mg/l is typically of young landfill, whereas this ratio drops to range of 0.05 mg/l to 0.2 mg/l in mature landfill. The BOD_5/COD ratio decreases as the age of the landfills increases (Iren, 1996). The mean value of BOD_5 shows different values between three surface waters. The greatest concentration of 513.13 mg/l was measured at the upstream station, whereas the lowest concentration of 497.47 mg/l was measured at the downstream station. These results were high if compared to the result of unpolluted surface water which is 16.4 mg/l. Similarly to BOD_5, the greatest value was obtained from the upstream station, whereas the lowest value was obtained from the downstream station. These results were high if compared to the result of unpolluted surface water which is 54.63 mg/l. These results are not within the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment (YMWE 1999). The values of F^- which measured at the three leachates showed different values. The highest value of 50.8 mg/l was obtained from the leachate 1, whereas the lowest value of 37.40 mg/l was obtained from the leachate 3. From the other side, the concentration of Cl was fluctuated widely between the three leachates. The higher mean value of 3346.33 mg/l was measured at the first leachate site. Cl is a conservative contaminant and is not affected either by the biochemical processes taking place in the landfill body or by the natural decontamination reactions in which the leachates are involved during their penetration in the vadose zone. Therefore the chlorides constitute a serious threat for the aquifer of the area (Fatta et al. 1999). High F^- concentration was observed in particular in the first station so surface water and the second station exhibited high concentration than the recommended limit of irrigation purpose (1.0 mg/l) determined by Yemen's Ministry of Water and Environment (YMWE 1999). The Cl^- concentrations measured at the three sites of surface water were different. The highest Cl^- concentration was reported at the upstream site with the value of 523.51 mg/l, whereas the lowest Cl^- concentration was reported at the downstream site with the value of 483.7 mg/l. These results were high if compared to the result of unpolluted surface water which is 56.8 mg/l. These results are also higher than the results (302 mg/l) obtained by (Mohammed & Nakhla 1995). The first leachate site was characterized by high levels of nitrogenous compounds concentrations in terms of nitrites, nitrate and ammonia-N. The ammonia range was considered to be in high concentration due to the anaerobic conditions that prevailed in the landfill which in return contributed to nitrate reduction towards ammonia gas phase (Fatta et al. 1999). The concentration of nitrogenous compounds indicates the occurrence of extensive anaerobic bacterial activities. Before the establishment of stringent regulations, sludges from wastewater treatment plants were most often spread on lands and buried in ditches as methods of disposal (Arcadio & Gregoria 2003). The concentrations of ammonia NH_3 for the surface water bodies are varied. The highest content was reported at the upstream site with the value of 261.87 mg/l, whereas the lowest content was reported at the downstream site with the value of 173.85mg/l. These results were high if compared to the result of unpolluted surface water which is 0.07 mg/l. The heavy metals examined in this study were lead (Pb), zinc (Zn), nickel (Ni), chromium (Cr), cadmium (Cd), and copper (Cu). Among all the trace elements analyzed, Zn showed the highest content followed by Cu, whereas Cd showed the lowest content followed by Cr content. On the other hand, the maximum concentrations of all trace elements are found in the first site. Generally, the concentrations of the metals (except Zn and Cu) were relatively low compared with the others researchers. This is due to the fact that the landfill receives mainly municipal solid waste and very low quantities of industrial waste. In addition, metals form insoluble sulphides since reductive conditions prevail in the landfill body (Fatta et al. 1999). Kjeldsen et al. (2002) & Christensen et al. (2001) who had attributed the modest concentration of trace elements in leachate to the strong attenuation by both sorption and precipitation which are believed to be significant mechanisms for metals immobilization and the subsequent low leachate concentrations. The concentrations of Pb, Ni and Cr of surface water were below the permissible results which recorded by YMWE (1999), WHO (2006), Saudi Arabia Standard (2000), Oman Standard (1993), Jordanian Standard (2002), Kuwait Standard (2001) and FAO (1985). On the contrary, the concentrations of Zn and Cu were high if compared to the standards, while the Cd concentration was not detected. Additionally, the concentrations of heavy metals in unpolluted surface water were not detected with the exception of Zn and Cu concentrations. This indicated the affected of surface water by raw wastewater.

Physico-chemical parameters of groundwater at three sites

The comparison of insitu parameters for Al-Sahool, Mitm and Al-Sayyadah areas is given in Table 1. The pH value for all groundwater sampling sites was about neutral in which the range being 7.36-7.99. The highest value was recorded at Mitm area, whereas the lowest value was recorded at Al-Sahool area. If the pH is above 7, this will indicate that water is probably hard and contains calcium and magnesium (David 2004). However, these are in agreement with the range values of 6.5 to 9 determined by Yemen's Ministry of Water and Environment (YMWE 1999). Also these results are in agreement with the range values 6.5 to 9.5 determined by WHO (2004) which is required for drinking water.

Table 1: Comparisons of *In-situ* parameters between three areas

Parameters	Al-Sahool area					Mitm area					Al-Sayyadah area				
	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5
pH	7.87	7.36	7.37	7.70	7.71	7.57	7.47	7.99	7.71	7.84	7.60	7.62	7.60	7.64	7.55
T	25.1	25.47	27.03	26.27	28	24.9	25	23.06	21.9	24.41	23.43	23.9	24.7	22.9	23.43
EC (µS/cm)	811	4825.6	3137.7	1056.1	850.8	644	693	1477.1	1438.1	955.6	730	682.3	734.3	624.5	686.7
TDS(mg/l)	527.15	3136.6	2039.5	686.47	553.04	418.6	450.45	960.12	934.74	621.16	474.5	443.52	472.53	405.93	446.33
DO (mg/l)	6.7	1.37	2.07	2.93	3.3	3.53	3.83	3.07	2.37	2.28	2.73	3.4	3.33	5.13	4.4

High EC concentrations were observed in particular at Al-Sahool area (BH2 with the value of 4825.57 µS/cm, BH3 with the value of 3137.73 µS/cm and BH4 with the value of 1056.10 µS/c m) followed by Mitm area (BH3 with the value of 1477.11 µS/c m, BH4 with the value of 934.74 µS/c m and BH5 with the value of 621.16 µS/cm). This indicates the affect of these two areas by landfill and wastewater respectively. On the other hand, high EC value of 734.3 µS/cm at Al-Sayyadah area exhibited lower concentrations than the recommended limit (1000 µS/cm) which set by YMWE (1999) and WHO (2004). Suman et al. (2006) mentioned that, the EC is a valuable indicator of the amount of material dissolved in water whereas Fatta et al. (1999) mentioned that, the high values of EC can be attributed to the high levels of the various anions. The values of total dissolved solids were in the range 418.6-3136.62 mg/l. The highest value was found at Al-Sahool area (BH2 with the value of 3136.62 mg/l and BH3 with the value of 2039.52 mg/l followed by Mitm area (BH3 with the value of 960.12 mg/l and BH4 with the value of 934.7 mg/l, whereas the lowest value was found at Al-Sayyadah area (BH4 with the value of 405.93 mg/l. 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 (WHO 2004). DO values for all groundwater samples were varied from 1.3 to 6.7 mg/l. The lowest concentration of DO in BH1 with the value of 1.37 mg/l, BH2 with the value of 2.07 mg/l and BH3 with the value of 2.93

mg/l at Al-Sahool area indicate the effect of these boreholes by the migration of leachate from the body of the landfill. The lowest concentration of DO in BH3 with the value of 3.07 mg/l, BH4 with the value of 2.37 mg/l, and BH5 with the value of 2.28 mg/l indicates that the effect of these boreholes by the migration of polluted surface water from the body of valley, and also indicates that these boreholes are rich with organic matter where bacteria used the oxygen to biodegrade it.

Table 2: Comparisons of major anions and nitrogenous compounds between three areas

Parameters	Al-Sahool area					Mitm area					Al-Sayyadah area				
	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5
Fe (mg/l)	0.025	0.644	0.205	0.160	0.095	0.046	0.050	0.032	0.066	0.038	0.034	0.034	0.018	0.051	0.057
Na (mg/l)	18.3	116	76.22	56.75	55.20	45.22	46.42	72.83	68.44	47.45	29.56	37.31	58.94	42.17	34.67
K (mg/l)	0.83	1.83	1.25	1.99	1.14	0.98	0.88	3.27	3.59	3.04	1.31	1.182	0.77	1.233	1.34
Ca (mg/l)	100	534	220.93	129.07	103.33	80.4	88.67	192.53	196.93	122	108.67	83.73	79.86	72.4	86.27
Mg (mg/l)	27.84	180.35	72.55	44.36	36.8	18.96	23.44	42.65	43.84	30.89	26.31	16.88	18	16.65	25.84
T.H (mg/l)	366	2089.3	854.33	507.33	412.67	280	319	659.33	633	432	381.3	302	274.7	257.7	323.3

For Al-Sayyadah area the high values of DO indicating the absence of E.*coli* bacteria. The comparison of Major anions and nitrogenous compounds for Al-Sahool, Mitm and Al-Sayyadah areas are given in Table 2. Fluoride was found in high concentrations in BH2 at Al-Sahool area while floride was found in low concentrations in BH2 at Al-Sayyadah area. YMWE (1999) and WHO (2004) recommended F^- concentration1.5 mg/l. This means that, BH2 is contaminated by F and the reason may be its effect by the leachate from the landfill. On the other hand, F concentrations for all other boreholes did not pose any water quality problem. High chloride concentrations were observed in particular at Al-Sahool area (BH2 with the value of 2376.31 mg/l, BH3 with the value of 818.73 mg/l and BH4 with the value of 336.7 mg/l) followed by Mitm area (BH3 with the value of 326.72 mg/l, BH4 with the value of 309.34 mg/l and BH5 with the value of 214.6 mg/l. Increase in Cl level is injurious to people suffering from diseases of heart or kidney (WHO, 2006). The Cl ion is the best indicator for detecting the presence of leachate in the groundwater (Bouwer 1978). The high Cl values were far higher than the YMWE (1999) and WHO (2004) guidelines. It can be said that, the high concentrations of Cl at Mitm area can be attributed to migration of polluted surface water to the groundwater. On the other hand, Cl concentrations for all other boreholes did not pose any water quality problem. The concentrations of SO_4 and NO_3^- did not pose any sign of water quality problems for all groundwater samples at all three areas. The reason may be due to the low concentrations of these parameters below the standard acceptable levels of drinking water determined by YMWE (1999) and WHO (2004). The concentrations of NO_2 for all groundwater samples exhibited arrange of values between 0.011 and 0.604 mg/l. The highest concentration was measured in BH5 with the value of 0.604 mg/l at Mitm area followed by BH2 with the value of 0.41 mg/l and BH3 with the value of 0.123 mg/l at Al-Sahool area. The NO_2 level in BH2 and BH3 at Al-Sahool area as well as BH5 at Mitm area are high compared to the standard acceptable levels of drinking water determined by YMWE (1999) and WHO (2004). The reason may be due to the migration of leachate from the body of Ibb landfill as well as due to the migration of polluted surface water to these boreholes respectively. The NH_3-N values were in the range of 0.01-2.28 mg/l. The maximum value was recorded in BH2 with the value of 2.28 mg/l and BH3 with the value of 0.49 mg/l at Al-Sahool area, followed by at Mitm area in BH5 with the value of 0.906 mg/l. The ammonia concentrations was quite evidence of the effect of the landfill leachate (Fatta et al. 1999). The low concentrations of NH_3-N at Al-Sayyadah area and the other boreholes at Mitm and Al-Sahool areas did not pose any water quality problems. The comparison of major cations for Al-Sahool, Mitm and Al-Sayyadah areas are shown in Table 2. The concentrations of Fe were in the range of 0.018-0.64 mg/l. Higher Fe concentration was only observed in BH2 with the value of 0.64 mg/l at Al-Sahool area and exhibited higher concentration than that recommended limit 0.3 mg/l which determined by YMWE (1999) and WHO (2004). This indicates the effect of this borehole by leachate migration. The low concentrations of Fe in the other boreholes for all areas did not pose any water quality problems. K and Na concentrations for all groundwater samples were in quite low levels in relation with the standard acceptable levels of drinking water determined by YMWE (1999) and WHO (2004). Ca concentration was found at low concentration only in BH4 with the value of 72.4 mg/l at Al-Sayyadah area. The other boreholes Ca concentrations were higher levels than those reported by YMWE (1999) and WHO (2004). For Al-Sayyadah area the reason may be due to the geological, chemical and physical properties of the aquifer. Beside the reason at Mitm and Al-Sahool areas due to the wastewater and leachate respectively. The Mg concentrations were found to be between 16.65 and 180.35 mg/l. At Al-Sayyadah area the Mg concentrations did not pose any water quality problems. With the exception of Mg concentration in BH1 with the value of 27.84 mg/l at Al-Sahool area and BH1 with the value of 18.96 mg/l and BH2 with the value of 23.44 mg/l at Mitm area, the other boreholes show high Mg concentrations. Multivalent cations, particularly Ca^{2+} and Mg^{2+} are often present at a significant concentration in natural waters. These ions are easily precipitated and in particular react with soap to make it difficult to remove scum. Ca^{2+} and Mg^{2+} are the important parameters for total hardness. The excess of Ca^{2+} causes concretions in the body such as kidney or bladder stones and irritation in urinary passages (Suman et al. 2006). Total hardness values varied from 257.7 to 2089.3 mg/l. The highest concentration was obtained at Al-Sahool area followed by Mitm area. This means that water in BH2, BH3, BH4 and BH5 at Al-Sahool area are very hard, and BH2 and BH3 are the most affected boreholes by leachate seepage from the body of the landfill. On the other hand, the high concentration of hardness at Mitm area in BH3, BH4 and BH5 are due to the polluted surface water. On the contrary, the concentration of hardness in all boreholes did not pose any water quality problems because the concentration of hardness are below the standard acceptable levels of drinking water determined by YMWE (1999) and WHO (2004). The comparison of heavy metals for Al-Sahool, Mitm and Al-Sayyadah areas are given in Table 4. The concentrations of Ni, Pb, Cd and Cu were high at Al-Sahool area, while only Cu concentrations were high at Mitm area. The concentration of these metals was found to be close to the permissible limit in groundwater samples. This likely indicates that these metals may be adsorbed by the soil strata or by the organic matter in soil (Suman *et al.*, 2006). For Al-Sayyadah area the concentration of heavy metals were low levels in relation with the standard acceptable levels of drinking water determined by YMWE (1999) and WHO (2004). The reason may be due to the absence of source of contamination. It can be said that, Al-Shool area is the most contaminated area by most of physico-chemical parameters compared to the other two areas. The leachate migrated from the upstream to the downstream area following the local and regional groundwater flow. This leachate migration towards the downstream area was found to affect the groundwater quality and lead to its inorganic pollution.

Table 3: Comparisons of major cations between three areas

Parameters	Al-Sahool area					Mitm area					Al-Sayyadah area				
	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5
F^- (mg/l)	0.39	2.44	0.663	0.595	0.57	0.381	0.495	0.50	0.56	0.89	0.71	0.34	0.65	0.54	0.56
Cl^- (mg/l)	113.6	2376.3	818.7	336.7	211.6	107.9	118.5	326.7	309.3	214.6	120.9	102.5	128.3	100.7	110.1
SO_4^{-2}(mg/l)	20.5	57.69	41.08	34.01	22.14	26.69	40.83	107.43	97.28	67.92	33.76	31.27	38.55	28.68	34.13
NO^{2-}(mg/l)	0.017	0.409	0.123	0.082	0.028	0.034	0.011	0.043	0.052	0.604	0.023	0.054	0.035	0.013	0.015
NO^{3-}(mg/l)	7.1	20.33	14.68	15.11	12.77	13.06	11.86	21.17	8.67	8.78	18.11	12.27	25.64	13.94	17.5
NH_3-N(mg/l)	0.008	2.28	0.49	0.074	0.105	0.041	0.017	0.111	0.05	0.906	0.025	0.041	0.031	0.045	0.052

Table 4: Comparison of heavy metals between three areas

Parameters	Al-Sahool area					Mitm area					Al-Sayyadah area				
	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5	BH1	BH2	BH3	BH4	BH5
Pb (mg/l)	0.004	0.112	0.096	0.09	0.089	0.002	0.003	0.005	0.004	0.002	0.024	0.021	0.004	0.007	0.007
Zn (mg/l)	0.15	1.24	0.11	0.44	0.037	0.163	0.106	0.68	0.6	0.202	0.716	0.164	0.162	0.475	0.665
Ni(mg/l)	0.002	0.08	0.012	0.013	0.017	0.001	0.002	0.01	0.004	0.006	0.01	0.01	ND	ND	ND
Cr(mg/l)	0.001	0.007	0.004	0.007	0.0006	0.001	0.001	0.001	0.002	0.003	0.005	0.01	ND	ND	ND
Cd (mg/l)	0.0012	0.063	0.06	0.051	0.040	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Cu (mg/l)	0.095	4.76	2.341	0.85	0.187	0.148	0.280	2.251	2.417	2.298	0.24	0.146	0.081	0.373	0.194

CONCLUSIONS

The first site of landfill leachate is characterized by the highest concentration parameters. The BOD_5/COD value of 0.1 mg/l obtained for leachate suggested the partially stabilization. All parameters, except Ni, and Cr, in Ibb landfill leachate exceeded the permissible limit required for treated wastewater discharge determined by Yemen's Ministry of Water and Environment (1999). The concentration of heavy metals in Ibb landfill leachate is below the standard acceptable levels of treated wastewater discharge determined by the Ministry of Water and Environment (1999). The upstream site of surface water is characterized by the highest concentration parameters. The results show the effect of surface water by fresh wastewater which directly discharges to the valley. The most parameters are not within the most standards which required for irrigation purpose. The results also show that three out of five boreholes are contaminated, where the 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 (YMWE, 1999) and WHO (2004). Leachate composition at Ibb landfill is very dangerous for polluting the groundwater, surface water as well as soil. Leachate composition during dry season contains high concentrations of most physico-chemical parameters in which the degree of pollution in this season was high compared to the other seasons. It is very important to mention that, all types of waste in Ibb landfill still without any treatment. So that Al-Sahool area stills the most contaminated area. Mitm area is the second contaminated area. Owing to the wastewater treatment plant in Ibb city still receive more than its capacity for treating wastewater so that the wastewater discharge directly to the valley. This wastewater will cause pollution of surface water in Mitm valley as well as will cause pollution of groundwater in this area. If this problem still without any solution, the pollution will increase to reach to the far areas. Al-Sayadah area is the clean area due to the absence of the source of contamination. In the future the pollution may be reach to this area due to the location of this area very close to the urban area.

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