

## Assessment of Groundwater and Surface Water Pollution at Mitm Area, Ibb City, Yemen

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**Abstract:** Groundwater and surface water samples were collected from Mitm area to study the possible impact of wastewater treatment percolation into the groundwater and surface water. The objective of the study is to assess the groundwater and surface water pollution due to wastewater treatment at Mitm area of Ibb city, in the Republic of Yemen. The concentrations of various physiochemical parameters include heavy metals (Pb, Zn, Ni, Cr, Cd, Cu) pH, temperature, Electrical Conductivity (EC), Total Dissolved Solids (TDS), and Dissolved Oxygen (DO), anions and nutrients (F<sup>-</sup>, Cl<sup>-</sup>, SO<sub>4</sub><sup>2-</sup>, NO<sub>2</sub><sup>-</sup>, NO<sub>3</sub><sup>-</sup>, NH<sub>3</sub>-N), major cations (Fe, Na, K, Ca, Mg) and parameters (COD, BOD<sub>5</sub>, and coliform group bacteria) were measured from the groundwater samples. The results 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). On the other hand, surface water is affected by the discharge of untreated wastewater. The concentrations of physiochemical parameters are above the standard acceptable levels which required for irrigation purpose adopted by Yemen's Ministry of Water and Environment (YMWE, 1999). Boreholes 1 and 2 are suitable for drinking water, whereas boreholes 3, 4 and 5 are not suitable for drinking water. Therefore, urgency for wastewater treatment at this site is recommended to prevent further contamination to surface and groundwater.

**Key words:** Surface water, groundwater, pollution, heavy metals

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### 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<sup>[10]</sup>.

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<sup>[6]</sup>.

Many countries have included wastewater reuse as an important dimension of water resources planning. In the more arid areas of Australia and the USA wastewater is used in agriculture, releasing high quality water supplies for potable use. Some countries, for example the Hashemite Kingdom of Jordan and the Kingdom of Saudi Arabia, have a national policy to reuse all treated wastewater effluents and have already made considerable progress towards this end<sup>[15]</sup>.

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.

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Thus, municipal wastewater effluents should be checked for trace element toxicity hazards, particularly when trace element contamination is suspected<sup>[13]</sup>.

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<sup>[4]</sup>.

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<sup>[3]</sup>.

Wastewater treatment plant of Ibb city was established for receiving 5000 m<sup>3</sup> per day, but now it receives more than 15000 m<sup>3</sup> per day. Untreated wastewater is going directly to the valley of Mitm area in which will cause the environmental pollution.

**MATERIAL AND METHODS**

Ibb city (Fig. 1) is located between Sana'a, the capital of Yemen, and Taiz governorates. Ibb city is located at latitude 13°58'48" and longitude 44°10'48". Ibb is situated in a fault controlled valley close to the main watershed of the Wadi Zabid at an elevation of about 2000m above sea level.

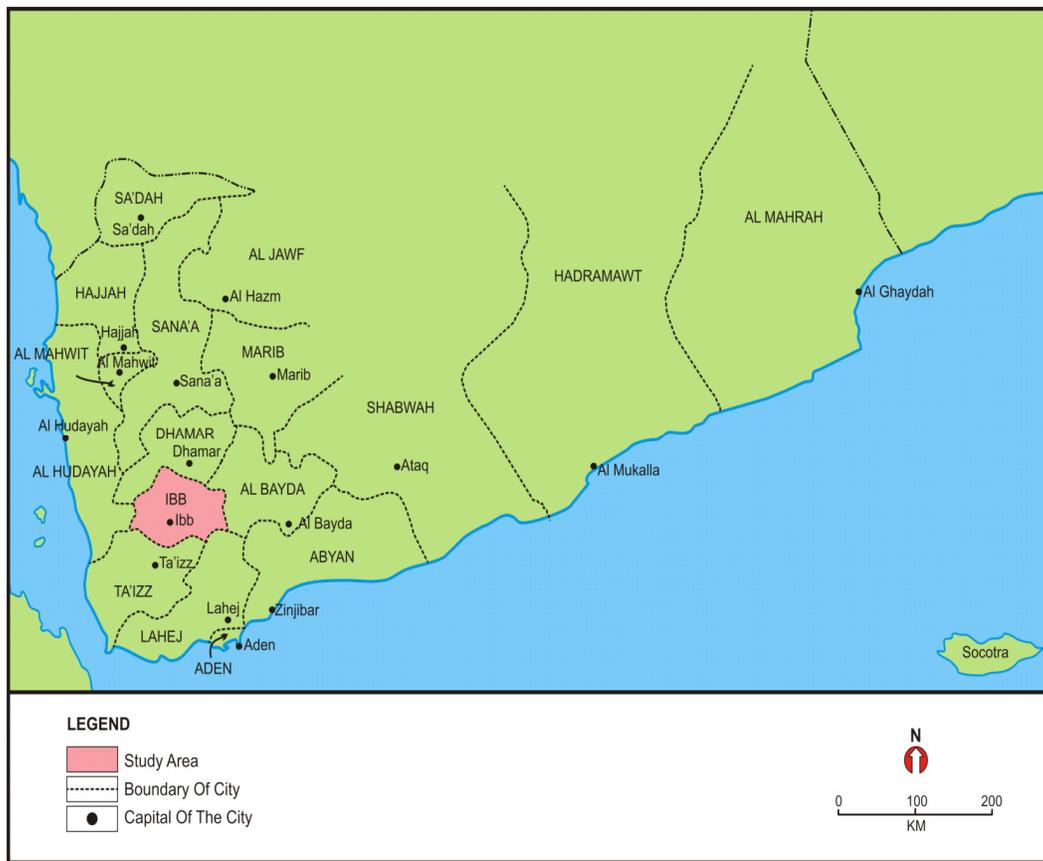


Fig. 1: Location of Ibb city

Figure 1 location of Ibb city Groundwater samples were collected from five boreholes. Two of these boreholes are located before wastewater treatment plant, whereas the other three boreholes are located after wastewater treatment pant. Surface water samples were also

collected from three different sites, the upstream, the middle, and the downstream of Mitm valley (Fig. 2). Glass and polyethylene bottles were used to collect groundwater samples. Water samples preserved for BOD<sub>5</sub> and COD tests were collected in polyethylene

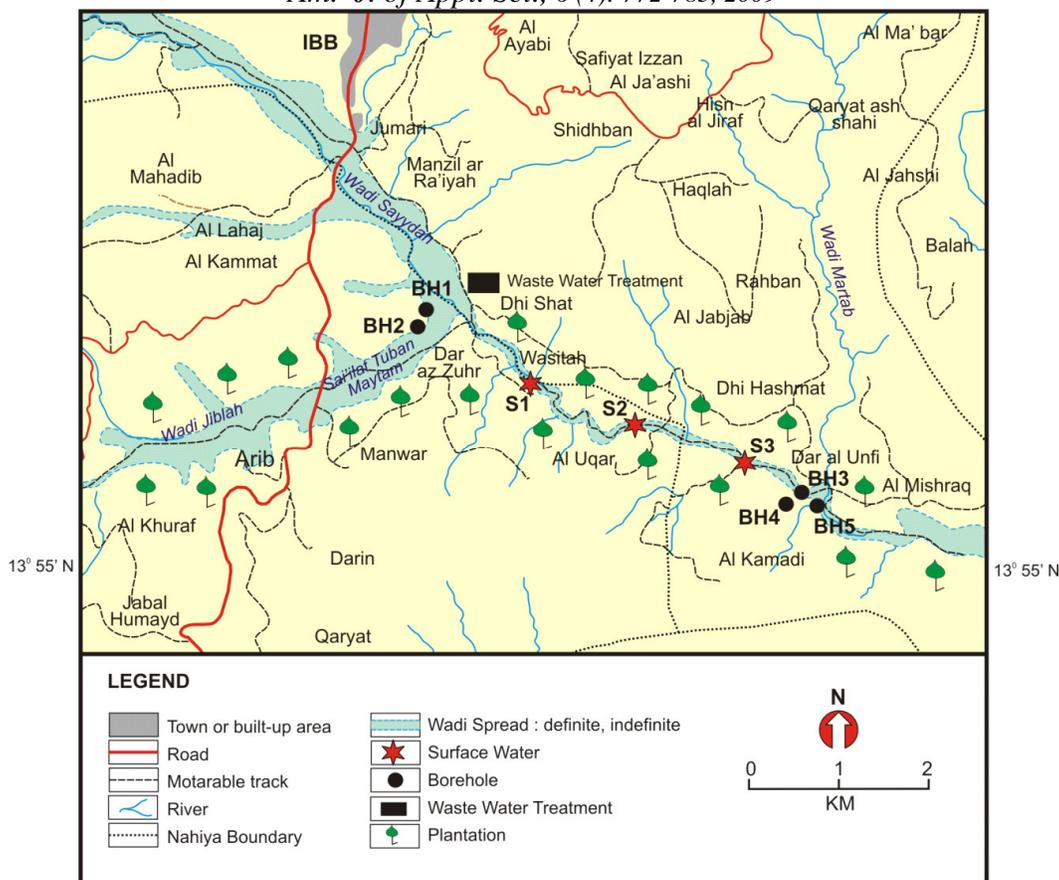


Fig. 2: Locations of groundwater and surface water samples

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.

The laboratory of Ibb Water and Sanitation Local Corporation (IWSLC) was used for analyzing the 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  $NH_3$ . 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 Meterology 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. 25mL of water samples was placed in Erlenmeyer flask, and then Diphenylcarbazone reagent was added to the sample. The solution was blue-green, when Mercuric Nitrate was added as a titrant, the

color of solution changed from blue-green to purple, making the end point of the titrant.

Calcium was measured by the EDTA titrimetric methods which involves the use of solutions of ethylene di amin titra acetic acid. 25ml of water sample was placed in a conical flask, and then 2mL of buffer solution was added to the sample. Man Ver 2 Calcium indicator was also added to the sample. The solution was wine red, when EDTA was added as a titrant, the color of solution changed from wine red to blue, making the end point of the titrant.

The hardness was measured by the EDTA titrimetric methods which involves the use of solutions of ethylene di amin titra acetic acid. 25mL of water sample was placed in a conical flask, and then 2mL of buffer solution was added to the sample. Man Ver 2 Hardness indicator was also added to the sample. The solution was wine red, when EDTA was added as a titrant, the color of solution changed from wine red to blue, making the end point of the titrant.

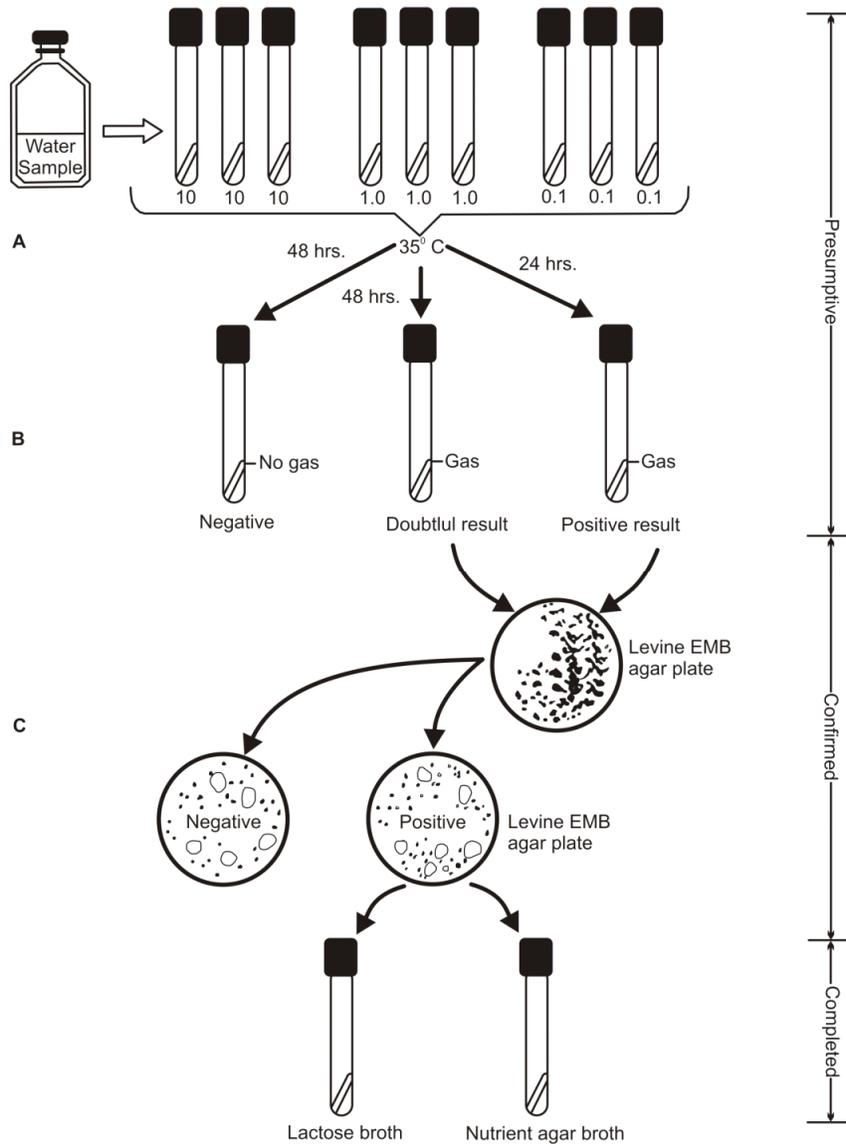


Fig. 3: Bacteriological analysis of water for coliform bacteria

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

$$\text{Total hardness (as CaCO}_3\text{)} = 2.497 [\text{Ca}^{2+}, \text{mg L}^{-1}] + 4.118 [\text{Mg}^{2+}, \text{mg L}^{-1}].$$

Then

$$4.118 [\text{Mg}^{2+}, \text{mg L}^{-1}] = \text{Total hardness (as CaCO}_3\text{)} - 2.497 [\text{Ca}^{2+}, \text{mg L}^{-1}]$$

Where

$$\text{Ca hardness} = \text{Ca ion} \times 2.5$$

$$\text{Mg hardness} = \text{Mg ion} \times 4.11$$

**Microbiological analysis:** Nine tubes of lactose broth (Fig. 3) were prepared according to the size of the water sample i.e. 0.1 mL, 1 mL, and 10 mL respectively for all water samples. The test tubes are placed in incubator at 35°C for 24 hours 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 Methylene Blue agar (EMB) was used in which contains methylene blue that inhibits coliforms. The plates of Eosin Methylene 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 into lactose broth. The lactose broth showed acid and gas production confirming the presence of coliform bacteria.

**RESULTS AND DISCUSSIONS**

**In situ parameters:** The results of the measured in situ parameters including pH, Temperature (T), Electrical Conductivity (EC), Total Dissolved Solids (TDS) and Dissolved Oxygen (DO) are shown in Table 1.

The pH values of all boreholes are shown in Table 1. The highest value of 7.7 is measured in BH5, whereas the lowest value of 7.3 is measured in BH4. The pH values are close to the results (7.6) obtained by Header *et al.*<sup>[9]</sup>. These results are also in agreement with the range values set by Yemen's Ministry of Water and Environment<sup>[17,15]</sup>. On the other hand, the pH values of all surface water are also shown in Table 1. The highest value of 8.0 is measured at the downstream site, whereas the lowest value of 7.3 is measured at the upstream site. 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<sup>[5]</sup>. The normal pH range for irrigation water is from 6.5-8.4. pH values outside this range are a good warning that the water is abnormal in quality<sup>[13]</sup>. This means that, pH values for boreholes and surface water are in the normal values for drinking water and for irrigation purpose.

The temperature measurements between boreholes are very close. The highest value is measured in BH2 (24.0° C), whereas, the lowest values in BH 4 (21.6°

C). These results are in agreement with the range values set by Yemen's Ministry of Water and Environment<sup>[14,15]</sup>. For the surface water, the highest value is measured at the downstream site, whereas, the lowest value is at the upstream site. Surface waters are, of course, subject to the effect of ambient temperatures and can be very warm during summer. The temperature of water affects the efficiency of treatment units. For example, in cold temperatures, the viscosity increases. This, in turn, diminishes the efficiency of settling of the solids that the water may contain because of the resistance that the high viscosity offers to the downward motion of the particles as they settle. Pressure drops also increase in the operation of filtration units, again, because of the resistance that the higher viscosity offers<sup>[2]</sup>.

Electrical Conductivity (EC) values show very different results between the boreholes. The highest value is recorded in BH4 (1544.17µS/cm), whereas the lowest value is recorded in BH2 (639µS/cm). The high values of EC in BH3, BH4, and BH5 are not within the range values of 450-1000µS/cm determined by Yemen's Ministry of Water and Environment<sup>[14,15]</sup> which required for drinking water. On the other hand, EC values in BH1 and BH2 are within the Yemen standard value which is required for drinking water and this means that these two boreholes are not affected by the effluent of wastewater treatment plant. The high values of EC in BH3, BH4, and BH5 can be related to the effect of surface water seepage towards these boreholes.

Electrical Conductivity (EC) values show variety results between three surface waters. The highest value is obtained at the upstream site with the value of 2646.65 µS/cm, whereas the lowest value is obtained at the downstream site with the value of 2585 µS/cm.

Table1: In situ Parameters in Mitm area

Parameter	pH	T	EC (µS/cm)	DO (mg <sup>-1</sup> )	TDS (mg <sup>-1</sup> )
Surface water 1	7.93	23.14	2646.65	1.10	1720.000
Surface water 2	7.97	23.49	2610.00	1.15	1696.500
Surface water 3	8.00	23.80	2585.00	1.20	1680.250
BH1	7.58	23.00	736.00	3.10	478.400
BH2	7.65	24.00	639.00	3.20	415.350
BH3	7.70	22.77	1461.33	0.80	949.865
BH4	7.30	21.60	1544.17	0.70	1003.710
BH5	7.68	22.73	1365.83	0.60	887.790
YMWE, <sup>[17]</sup>	6.5-9	25.00	450-1000	-	1500.000
WHO, <sup>[15]</sup>	6.5-9.5	-	-	-	1200.000

These results are high compared to the standard acceptable levels of drinking water and irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[14,15]</sup> Conductivity was used to give an

idea of the amount of dissolved chemicals in water, and 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.

Table 2: The composition of wastewater at Ibb treatment plant

Parameters	pH	T	EC ( $\mu\text{S/cm}$ )	DO $\text{mg}^{-1}$	TDS $\text{mg}^{-1}$	BOD <sub>5</sub> ( $\text{mg}^{-1}$ )	COD( $\text{mg}^{-1}$ )
Reading	7.6	24	3050	1.2	1982.5	1420	1820

Table 3: Water Quality Dissolved Oxygen ( $\text{mg}^{-1}$ )

Good	Above 8.0
Slightly polluted	6.5 - 8.0
Moderately polluted	4.5 - 6.5
Heavily polluted	4.0 - 4.5
Severely polluted	4.0

Table 4: BOD<sub>5</sub> and COD at Mitm valley

Parameters	BOD <sub>5</sub>	COD
Surface water 1	728.4	982.40
Surface water 2	723.2	970.67
Surface water3	721.8	959.55
YMWE, <sup>[17]</sup>	150.0	500.00
Saudi Arabia, <sup>[14]</sup>	40.0	150.00
Oman, <sup>[12]</sup>	15.0	150.00
Jordanian, <sup>[8]</sup>	60.0	150.00

Conductivity is not a problem in itself and just because it is above certain level does not mean that the water will cause illness<sup>[5]</sup>. In general, surface water is affected by untreated wastewater which discharges directly into the stream. Table 2 shows the composition of wastewater at Ibb wastewater treatment plant.

The Dissolved Oxygen (DO) values of the surface water show approximately different values. 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. Because the concentration of dissolved oxygen is never very large, oxygen-depleting processes can rapidly reduce it to near zero in the absence of efficient aeration mechanisms. Table 3 shows the water quality dissolved oxygen. This means that all surface waters are severely polluted.

Dissolved Oxygen (DO) measurements are varied. The highest concentration of  $3.2\text{mg}^{-1}$  is measured in BH2, whereas the lowest concentration of  $0.6\text{mg}^{-1}$  is measured in BH5. The lowest concentration of DO in BH3, BH4, and BH5 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. It has been assumed that these pollutants are transported from polluted surface water and most likely will be transported to the groundwater and pollute it.

The concentrations of total dissolved solids (TDS) are different between the three surface waters. The highest value of  $1720\text{mg}^{-1}$  is measured at the upstream

site, whereas the lowest value of  $1682\text{mg}^{-1}$  is measured at the downstream site. These results are higher than the Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup> On the other hand these results are in agreement with the range values ( $450\text{-}3000\text{mg}^{-1}$ ) set by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup> and Saudi Arabia standard which required for irrigation purpose.

The concentrations of Total Dissolved Solids (TDS) are also different between boreholes. The highest value of  $1003.71\text{mg}^{-1}$  is measured in BH4, whereas, the lowest value of  $415.35\text{mg}^{-1}$  is measured in BH2. The high concentrations of TDS in BH3, BH4, and BH5 can be attributed to the affect of these boreholes by polluted surface water. On the contrary, the low concentrations of TDS in BH1 and BH2 mean that these two boreholes did not affect these two boreholes by polluted surface water. Although the concentrations of TDS in BH3, BH4, and BH5 are high, these concentrations are within the standard acceptable levels of drinking water determined by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup>.

The concentration of BOD<sub>5</sub> did not show different values between three surface waters (Table 4). The greatest concentration of  $728.4\text{mg}^{-1}$  is measured at the upstream site, whereas the lowest concentration of  $721.8\text{mg}^{-1}$  is measured at the downstream site. These results are not within the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[14,15]</sup>. On the other hand, these results are higher than the Saudi Arabia standard<sup>[14]</sup>, Oman standard<sup>[12]</sup> and Jordanian standard<sup>[8]</sup>. The BOD<sub>5</sub> of sewage varies from several hundred to about  $1000\text{mg}^{-1}$  for raw sewage, and from about  $10\text{ to }20\text{mg}^{-1}$  for good quality secondary effluent<sup>[13]</sup>. This means that, the fresh wastewater is going directly to the valley and polluted the surface water body.

The COD values of the three surface waters showed different values. The highest value of  $982.4\text{mg}^{-1}$  is measured at the upstream site, whereas, the lowest value of  $959.55\text{mg}^{-1}$  is measured at the downstream site. These results are also not within the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[14,15]</sup>. On the other hand, these results are higher than the Saudi Arabia standard<sup>[14]</sup>, Oman standard<sup>[12]</sup> and Jordanian standard<sup>[8]</sup>.

Table 5: Concentration of major anions and nitrogenous compounds

Parameter	F ( $\text{mg}^{-1}$ )	Cl ( $\text{mg}^{-1}$ )	SO <sub>4</sub> <sup>2-</sup> ( $\text{mg}^{-1}$ )	NO <sub>2</sub> <sup>-</sup> ( $\text{mg}^{-1}$ )	NO <sub>3</sub> <sup>-</sup> ( $\text{mg}^{-1}$ )	NH <sub>3</sub> -N ( $\text{mg}^{-1}$ )
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Surface water 1	3.725	564.45	255.00	0.708	55.84	261.87
Surface water 2	3.496	560.90	200.54	0.705	55.00	181.85
Surface water 3	3.309	514.75	168.00	0.705	54.00	173.85
YMWE, <sup>[17]</sup>	1.000	4-10	-	-	-	-
WHO, <sup>[15]</sup>	1.000	4-10	-	-	-	-
Saudi Arabia standard <sup>[14]</sup>	1.000	100.00	600.00	-	10.00	5.00
Oman standard <sup>[12]</sup>	1.000	650.00	400.00	-	50.00	5.00
Jordanian standard <sup>[8]</sup>	1.500	350.00	350.00	-	45.00	-

Table 6: Concentration of major anions and nitrogenous compounds

Parameter	F (mg <sup>-1</sup> )	Cl <sup>-</sup> (mg <sup>-1</sup> )	SO <sub>4</sub> <sup>-2</sup> (mg <sup>-1</sup> )	NO <sub>2</sub> <sup>-</sup> (mg <sup>-1</sup> )	NO <sub>3</sub> <sup>-</sup> (mg <sup>-1</sup> )	NH <sub>3</sub> -N (mg <sup>-1</sup> )
BH1	0.442	110.00	19.683	0.029	14.17	0.031
BH2	0.487	114.70	42.400	0.012	11.67	0.051
BH3	0.510	313.47	117.700	0.022	11.83	0.134
BH4	0.550	341.51	122.500	0.054	11.00	0.074
BH5	0.720	281.10	101.750	1.684	5.83	2.554
YMWE, <sup>[17]</sup>	1.500	250.00	250.000	0.100	50.00	0.500
WHO <sup>[15]</sup>	1.500	250.00	250.000	0.100	50.00	-

**Major anions and nitrogenous compounds:** These include Fluoride (F), Chloride (Cl<sup>-</sup>), Sulfate (SO<sub>4</sub><sup>-2</sup>), Nitrites (NO<sub>2</sub><sup>-</sup>), Nitrates (NO<sub>3</sub><sup>-</sup>) and ammonia-N (NH<sub>3</sub>-N). The results are shown in Table 5 and 6.

The F concentrations measured at the three sites of surface water are very close the values. The highest F concentration is reported at the upstream site with the value of 3.725 mg<sup>-1</sup>, whereas the lowest F concentration is reported at the downstream site with the value of 3.309 mg<sup>-1</sup>. These results are grater than the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup>. These results compared to the Kuwait standard are very low. On the other hand these results are also high compared to the Saudi Arabia standard<sup>[14]</sup>, Oman standard<sup>[12]</sup> and Jordanian standard<sup>[8]</sup>. For the boreholes, the highest F concentration is reported in BH5 with the value of 0.75 mg<sup>-1</sup>, whereas the lowest F concentration is reported in BH1 with the value of 0.442mg<sup>-1</sup>. These results are high compared to the results obtained by Header *et al.*<sup>[9]</sup>. These results, on other hand, are in agreement with the standard acceptable levels of drinking water determined by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup>.

The Cl<sup>-</sup> concentrations measured at the three sites of surface water are different. The highest Cl<sup>-</sup> concentration is reported at the upstream site with the value of 564.45 mg<sup>-1</sup>, whereas the lowest Cl<sup>-</sup> concentration is reported at the downstream site with the value of 514.75 mg<sup>-1</sup>. These results are higher than the results (302 mg<sup>-1</sup>) obtained by Mohammed and Nakhla<sup>[11]</sup>. These results are lower than the Oman standard<sup>[12]</sup>. On the contrary, these results are not within the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup>, Saudi Arabia standard<sup>[14]</sup>,

Jordanian standard<sup>[8]</sup> and Kuwait standard (2001). According to FAO<sup>[7]</sup>, the Cl<sup>-</sup> concentration for surface irrigation is about 106.5 mg<sup>-1</sup> is considered slight to moderate. This indicates that, surface water is polluted and affected by the discharge of untreated wastewater directly to the valley. For the boreholes, the highest Cl<sup>-</sup> concentration is reported in BH4 with the value of 341.51 mg<sup>-1</sup>, whereas the lowest Cl<sup>-</sup> concentration is reported in BH1 with the value of 110 mg<sup>-1</sup>.

The Cl<sup>-</sup> concentrations in BH1 and BH2 are lower than the results (198.5 mg<sup>-1</sup>) obtained by Header *et al.*<sup>[9]</sup>, but the Cl<sup>-</sup> concentrations in BH3, BH4, and BH5 are high compared to the results obtained by Header *et al.*<sup>[9]</sup>. The high Cl<sup>-</sup> concentrations in these boreholes can be attributed to migration of polluted surface water to the groundwater.

The concentrations of sulfate at the three surface water bodies are 255 mg<sup>-1</sup>, 200 mg<sup>-1</sup> and 168 mg<sup>-1</sup> respectively. The concentrations of NO<sub>3</sub><sup>-</sup> at the three surface water bodies are 55.84 mg<sup>-1</sup>, 55 mg<sup>-1</sup> and 54 mg<sup>-1</sup> respectively. These results are low values compared to Oman standard<sup>[12]</sup>, Saudi Arabia standard<sup>[14]</sup> and Jordanian standard<sup>[8]</sup>. For the boreholes, the highest concentration of SO<sub>4</sub> is measured in BH4 with the value of 122.5 mg<sup>-1</sup>, whereas the lowest concentration is measured in BH1 with the value of 19.68 mg<sup>-1</sup>. The high concentrations of SO<sub>4</sub> in BH3, BH4, and BH5 compared to the low concentrations of SO<sub>4</sub> in BH1 and BH2 are due to the affected of these boreholes by polluted surface water. Although, the concentrations of SO<sub>4</sub> in BH3, BH4 and BH5 are high, but did not pose any significant water quality problem, because these results are within the standard acceptable levels of drinking water determined by YMWE and WHO<sup>[13,14,15]</sup>.

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. As the sludge decays, nitrates are formed. Thus, in some situations, these methods of disposal have resulted in the nitrates percolating down the soil causing excessive contaminations of the groundwater. Nitrogen is a major component of wastewater. People eat meat and meat contains protein that, in turn, contains nitrogen. Nitrogen in protein is needed by humans in order to survive which, in turn, produces wastewater that must be treated<sup>[2]</sup>.

The concentrations of ammonia NH<sub>3</sub> for the surface water bodies are different. The highest concentration is reported at the upstream site with the value of 261.87 mg<sup>-1</sup>, whereas the lowest concentration is reported at the downstream site with the value of 173.85mg<sup>-1</sup>. These results are very high compared to the Saudi Arabia standard<sup>[14]</sup>, Oman standard<sup>[12]</sup>. On the other hand, the concentrations of ammonia NH<sub>3</sub> for the boreholes are different. The highest concentration is measured in BH5 with the value of 2.554 mg<sup>-1</sup>, whereas, the lowest concentration is measured in BH1 with the value of 0.03 mg<sup>-1</sup>. The high concentration of NH<sub>3</sub> in BH5 is higher than the results obtained by Header *et al.*<sup>[9]</sup> and higher than the standard acceptable levels of drinking water determined by YMWE<sup>[13,14,15]</sup> and WHO. This means that, this borehole is the most affective boreholes by the polluted surface water.

Ammonia in wastewater is mixture of dissolved ammonia gas (NH<sub>3</sub>) and the ammonium ion (NH<sub>4</sub><sup>+</sup>), often referred to as 'free' and 'saline' ammonia, respectively. Free ammonia at concentrations >0.5 mg N/l is toxic to fish<sup>[6]</sup>.

According to Arcadio and Gregoria<sup>[2]</sup> the free ammonia may hydrolyze producing the ammonium ion according to the following reaction:



At pH levels below 7, the above equilibrium is shifted to the right and the predominant nitrogen species is NH<sub>4</sub><sup>+</sup>, the ionized form. On the other hand, when the pH is above 7, the equilibrium is shifted to the left and the predominant nitrogen species is ammonia.

The NO<sub>2</sub> levels in groundwater are varied. The highest level is recorded in BH5 with the value of 1.684

mg/l, whereas the lowest level is recorded in BH2 with the value of 0.012 mg/l. The NO<sub>2</sub> level in BH5 is close to the results obtained by Header *et al.*<sup>[9]</sup>. On the other hand, this value is high compared to the standard acceptable levels of drinking water determined by YMWE<sup>[13,14,15]</sup> and WHO. The reason may be due to the affect of this borehole by migration of polluted surface water to the groundwater.

The NO<sub>3</sub> 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<sup>[13]</sup>. In this study the combined of nitrate plus nitrite did not exceed 1. On the other hand, nitrite is oxidized into nitrate which can be quickly assimilated by plants or otherwise reduced again to nitrite and NH<sub>3</sub>.

**Major cations:** The major cations include Fe, Na, K, Ca, and Mg. Among all the cations analysed, Na showed high concentration levels at three surface water bodies. The Fe concentrations are lower than the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of Water and Environment<sup>[13,14,15]</sup>, WHO, Saudi Arabia standard, Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup>. The Na concentrations are greater than the results (227 mg<sup>-1</sup>) obtained by Mohammed and Nakhla<sup>[11]</sup>. The effect of sodium ions in irrigation water in reducing infiltration rate and soil permeability is dependent on the sodium ion concentration relative to the concentration of calcium and magnesium ions and the total salt concentration<sup>[13]</sup>. On the other hand, these results are also high compared to YMWE<sup>[15,17]</sup>, WHO and Jordanian standards<sup>[8]</sup>. The Ca concentrations are high compared to the results obtained by Mohammed and Nakhla<sup>[11]</sup>.

On the contrary, these results are lower than the Jordanian standard<sup>[8]</sup>. The Mg concentrations are lower than Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup>.

The distribution of Fe, 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 YMWE<sup>[15, 17]</sup> and WHO. The presence of sodium in drinking water can affect persons suffering from heart, kidney, or circulatory ailments. It may elevate blood pressures of susceptible individuals. Sodium is plentiful in the

Table 7: Concentration of major cations

Parameter	Fe (mg <sup>-1</sup> )	Na (mg <sup>-1</sup> )	K (mg <sup>-1</sup> )	Ca (mg <sup>-1</sup> )	Mg (mg <sup>-1</sup> )
Surface water 1	0.186	270	62.34	166.5	25.62
Surface water 2	0.173	296	62.00	166.5	24.66

Surface water 3	0.165	266	61.34	164.5	24.90
YMWE, <sup>[17]</sup>	5.000	3-9	-	-	-
WHO, <sup>[15]</sup>	5.000	3-9	-	-	-
Saudi Arabia standard <sup>[14]</sup>	2.000	-	-	-	-
Oman standard <sup>[12]</sup>	5.000	-	-	-	150.0
Jordanian standard <sup>[8]</sup>	5.000	230.0	-	230.0	100.0

Table 8: Concentration of major cations and hardness

Parameter	Fe (mg <sup>-1</sup> )	Na (mg <sup>-1</sup> )	K (mg <sup>-1</sup> )	Ca (mg <sup>-1</sup> )	Mg (mg <sup>-1</sup> )	Hardness (mg <sup>-1</sup> )
BH1	0.061	52.67	1.150	68.0	10.56	214
BH2	0.039	54.00	0.733	86.4	23.76	315
BH3	0.065	101.00	2.920	219.6	33.64	690
BH4	0.016	94.70	3.320	257.0	43.68	700
BH5	0.057	82.67	4.850	180.0	39.60	615
YMWE <sup>[17]</sup>	0.300	200.00	-	75.0	30.00	300
WHO, <sup>[15]</sup>	0.300	200.00	-	75.0	30.00	500

common table salt that people use to flavor food to their taste<sup>[2]</sup>.

Among all the cations analysed, Ca showed high concentration levels in the boreholes. The highest content value is measured in BH4 with the value of 257 mg/l, whereas the lowest content value is measured in BH1 with the value of 68 mg<sup>-1</sup>. the Ca contents in BH1 and BH2 are lower than the results obtained by Header *et al.*<sup>[9]</sup>. On the contrary, the Ca contents in BH3, BH4 and BH5 are greater than the results obtained by Header *et al.*<sup>[9]</sup>. The content values of Mg measured in the boreholes are varied. The highest content value is measured in BH4 with the value of 43.68 mg<sup>-1</sup>, whereas the lowest content value is measured in BH1 with the value of 10.56 mg<sup>-1</sup>. These results are low compared to the results obtained by Header *et al.*<sup>[9]</sup>. On the other hand, the Ca and Mg contents in BH3, BH4, and BH5 are not in agreements with the standard acceptable levels of drinking water determined by YMWE<sup>[14,15]</sup> and WHO<sup>[15]</sup>. This means that, the affected of these boreholes by polluted surface water.

The high concentration of hardness is reported in BH4 with the value of 700 mg<sup>-1</sup> followed by BH3 with the value of 690 mg<sup>-1</sup>, whereas the lowest concentration is reported in BH5 with the value of 615 mg<sup>-1</sup> Table 7. The concentration of hardness in BH1 and BH2 did not pose any water quality problems because the concentration of hardness are below the standard acceptable levels of drinking water determined by YMWE<sup>[17]</sup> and WHO<sup>[15]</sup>. On the other hand, the high concentration of hardness in BH3, BH4 and BH4 are due to the affected of these boreholes by polluted surface water. Softening is the term given to the process of removing ions that interfere with the use of soap. These ions are called hardness ions due to the presence of multivalent cations, mostly calcium and magnesium. In the presence of hardness ions, however, soap does not form the lather immediately but reacts with the ions, preventing the formation of lather and forming scum. Lather will only form when all the hardness ions are

consumed. This means that hard waters are hard to lather<sup>[2]</sup>.

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<sup>[5]</sup>. This means that, water in BH3, BH4 and BH5 is very hard water. Table 7 shows the levels of hardness of water and the type of water.

**Heavy metals:** 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 8. The highest concentrations of heavy metals are recorded at the upstream site. Zn concentration is the highest concentration of heavy metals with the value of 3.735mg<sup>-1</sup>, whereas the lowest concentration of heavy metals is recorded for Pb with the value of 0.001 mg<sup>-1</sup>, while the Cd and Cr are not detected.

The concentration of Pb and Ni are the highest at the upstream site, whereas the lowest concentration of Pb and Ni are in the downstream site. These results did not pose any water quality problems because these results are below the standard acceptable levels of irrigation purpose determined by Yemen's Ministry of

Table 9: Levels of hardness of water and the type of water

Water type	Equivalent
Soft	< 50 mg L <sup>-1</sup> as CaCO <sub>3</sub>
Moderately hard	50-150 mg L <sup>-1</sup> as CaCO <sub>3</sub>
Hard	150-300 mg L <sup>-1</sup> as CaCO <sub>3</sub>
Very hard	> 300 mg L <sup>-1</sup> as CaCO <sub>3</sub>

Water and Environment <sup>[13,14,15]</sup> WHO, Saudi Arabia standard<sup>[14]</sup>, Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup>.

Zn concentrations for three surface water sites are higher than the standard acceptable levels of irrigation purpose determined by Yemen’s Ministry of Water and Environment<sup>[13,14,15]</sup>, WHO and Saudi Arabia standard. On the contrary, these results are low compared to the Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup>. This means that, the affective of surface water by fresh wastewater which directly discharge to the valley.

The highest concentration of Cu is recorded at the upstream site, whereas the lowest concentration is recorded at the downstream site. These results are high compared to the standard acceptable levels of irrigation purpose determined by Yemen’s Ministry of Water and Environment<sup>[13,14,15]</sup>, WHO, Saudi Arabia standard<sup>[14]</sup>, Jordanian standard<sup>[8]</sup> and Oman standard<sup>[12]</sup>. This means that, the affective of surface water by fresh wastewater which directly discharge to the valley.

For the boreholes the concentration of heavy metals are shown in Table 10. Cu concentration is the highest concentration of heavy metals with the value of

2.75mg<sup>-1</sup>, whereas the lowest concentration of heavy metals is recorded for Pb with the value of 0.001 mg/l, while the Cd and Cr are not detected (Table 9). The concentrations of Pb, Zn and Ni did not pose any water quality problems because of the agreement of these results with standard acceptable levels of drinking water determined by YMWE<sup>[14,15]</sup> and WHO<sup>[13]</sup>. The concentrations of Cu in all boreholes are different. The highest concentration of Cu is recorded in BH4 with the value of 2.75 mg<sup>-1</sup>, whereas the lowest concentration of Cu is recorded in BH1 with the value of 0.11 mg<sup>-1</sup>. The high concentration of Cu in BH3, BH4 and BH5 are close to the results obtained by Header *et al.*<sup>[9]</sup>. On the other hand, these results are not in agreement with standard acceptable levels of drinking water determined by YMWE<sup>[14,15]</sup> and WHO<sup>[13]</sup> and this means that these boreholes are affected by migration of polluted surface water to the groundwater. On the contrary, the concentration of Cu in BH1and BH2 did not pose any water quality problems because the non affective of these two boreholes by polluted surface water.

Table 10: concentration of heavy metals at surface water bodies

Parameter	Pb (mg <sup>-1</sup> )	Zn (mg <sup>-1</sup> )	Ni (mg <sup>-1</sup> )	Cr (mg <sup>-1</sup> )	Cd (mg <sup>-1</sup> )	Cu (mg <sup>-1</sup> )
Surface water 1	0.007	3.735	0.013	0.00	0.00	2.634
Surface water 2	0.004	3.713	0.012	0.00	0.00	2.600
Surface water 3	0.001	3.671	0.011	0.00	0.00	2.576
YMWE <sup>[17]</sup>	5.0	2.000	0.500	0.10	0.01	0.200
WHO <sup>[15]</sup>	5.0	2.000	0.200	0.10	0.01	0.200
Saudi Arabia standard <sup>[14]</sup>	0.1	2.000	0.200	0.10	0.01	0.400
Oman standard <sup>[12]</sup>	0.1	5.000	0.100	0.05	0.01	0.050
Jordanian standard <sup>[8]</sup>	0.2	5.000	0.200	0.02	0.01	0.200

Table 11: concentration of heavy metals of groundwater

Parameter	Pb (mg <sup>-1</sup> )	Zn (mg <sup>-1</sup> )	Ni (mg <sup>-1</sup> )	Cr (mg <sup>-1</sup> )	Cd (mg <sup>-1</sup> )	Cu (mg <sup>-1</sup> )
BH1	0.000	0.157	0.001	0.00	0.000	0.110
BH2	0.008	0.784	0.000	0.00	0.000	0.163
BH3	0.005	0.494	0.0125	0.00	0.000	2.494
BH4	0.003	0.259	0.0110	0.00	0.000	2.750
BH5	0.001	0.316	0.0130	0.00	0.000	2.395
YMWE <sup>[17]</sup>	0.010	3.000	0.0200	0.05	0.003	1.000
WHO <sup>[15]</sup>	0.010	3.000	0.0200	0.05	0.003	1.000

**Bacteria:** The results of microbiological analysis are shown in Table 11 and 12. The results show that BH1 and BH2 did not show any microorganism bacteria, whereas BH3, BH4 and BH5 show the presence of 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. 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

Table 12: Microbiological results at Mitm valley

Parameter	3 of 10m each	3 of 1m each	3 of 0.1m each	MPN Index per 100m
Surface water 1	3	3	3	2400
Surface water 2	3	3	3	2400
Surface water 3	3	3	3	2400
BH1	0	0	0	0
BH2	0	0	0	0
BH3	3	3	2	1100
BH4	3	3	2	1100
BH5	3	3	2	1100
APHA, 1998	3	3	3	2400

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<sup>[13]</sup>

The group belongs to the genera *Escherichia*, *Aerobacter*, *Klebsiella* and *Paracolonobacterium* and mostly inhabits the intestinal tract of humans, although they could also be found in the outside environment. Although also found outside the intestinal tract, this group of organisms is used as an indicator for the presence of pathogens in waters. Surface waters can be used for drinking purposes after treatment, so effluents from sewage treatment plant discharges are limited for the acceptable concentrations of these organisms, thus the necessity for testing.<sup>[2]</sup>

### CONCLUSIONS

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<sup>[14,15]</sup> and WHO<sup>[13]</sup> (2004). Boreholes 3,4 and 5 are contaminated by coliform group bacteria. Boreholes 1 and 2 did not pose any water quality problems and this means that these boreholes are suitable for drinking water, whereas Boreholes 3, 4 and 5 are not suitable for drinking water. Therefore, urgency for wastewater treatment at this site is recommended to prevent further contamination to surface and groundwater.

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