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Influence of Urbanization on Water Quality Deterioration of Northern Wadi Shu′eib Catchment Area Springs, Jordan

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Abstract

This study investigates the effect of urbanization and informal residential settlements on the springs' water quality deterioration in Northern Wadi Shu′eib Catchment Area (NWSCA) that is mainly dominated by sedimentary rocks of the Upper Cretaceous Carbonate rocks. The present study examines ten representative springs out of twenty-two, in addition to the effluent of Salt Wastewater Treatment Plant (SWWTP). It also investigates the effect on water quality that is caused by urbanization and population growth around the recharge areas of the springs. It was found that the investigated springs are within the permissible limits of Jordanian Standards (JS) and World Health Organization (WHO) Guidelines for drinking-water quality for the parameters of pH, EC, turbidity, total hardness, total alkalinity, chloride, sulfate, sodium, potassium and iron. However, it exceeded the JS and WHO Guidelines for drinking-water quality for nitrate, phosphate, lead, Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and total Coliform.

Keywords: Urbanization, Wadi Shu′eib, Upper Cretaceous Carbonate rocks, Water Quality.

1. Introduction

Jordan is known to be one of the most water scarce countries in the world. More than 80% of the country is desert and about 90% of the annual rainfall is lost to evaporation with a share of 64% for agricultural purposes as irrigation water (MWI, 2004).

The growing demand for water supply is a result of the fast socio-economic development of Jordan and high population growth. Therefore, efforts were spurred to protect the quality of this limited water resource. NWSCA is mainly dependent on groundwater resources where water quality is at risk by groundwater hazards. It is experiencing rapid expansion with unsewered development and using septic tanks, thereby discharging to the unsaturated zone reaches groundwater where it affects water quality. Approximate times for septic effluent to pass the vadose zone to reach groundwater depend on the volume of effluent and the distance to water table. A septic plume in groundwater moves at a rate similar to the groundwater velocity (Robertson et al.,1991). The karst aquifer properties allow wastewater to recharge the springs very quickly and without any purification (Al-Kharabsheh and Ta'any, 2003). Therefore, the groundwater of the Upper Cretaceous Karst (carbonate) aquifer, which is prominent in the study area, is highly vulnerable. The inherent characteristics of the aquifer, namely, highly flow velocities, short residence time and fast hydraulic reactions accelerate groundwater pollution levels (Bender, 1974).

Werz (2006) found that highest risk intensity at Wadi Shu′eib area occurs in urban areas. The urban areas in the study area, often situated in karstified limestone's are not covered by auxiliary sediment or soil cover. This leads to a high vulnerable groundwater. Furthermore, the main contaminants are point source hazards caused by missing or leaking sewer systems, factor farms, manure heaps septic tanks and car service stations without unpaved floors and illegal waste dump.

McQuillan (2006) studied groundwater contamination by septic tanks effluents. He observed several health hazards from the contaminants, blue babies, neurotoxin and other specific outbreaks of disease. Furthermore, he suggested alternatives to conventional septic systems including advanced wastewater treatment units, which are like mini sewage treatment plants.

Foster (2001) investigated the interdependence of groundwater and urbanization in rapidly developing cities. He found that there are rather widespread indications of degradation of the groundwater resource-base caused by excessive exploitation and/or inadequate pollution control.

Minnesota Pollution Control Agency (1999) conducted a study to determine the effects of septic systems on groundwater quality in residential areas of Baxter, Minnesota. The agency reported that septic waste discharged to coarse-textured soils proceeds vertically through the unsaturated zone and into groundwater, through developing septic plume, which move with groundwater flow. It also found that median nitrate concentrations were significantly higher in areas with individual sewage treatment systems than in areas served by municipal sewers. Moreover, bacteria and Volatile Organic Compounds (VOCs) were found in septic effluent at all investigated sites.

The main objectives of this study are to determine the recent annual level of pollution fluctuations on these springs throughout the year, and classify the spring's′ water quality according to the biological and chemical properties. Furthermore, the interrelationships were pointed out between the results of the springs′ water analyses and recent pollution levels of these springs with the increased numbers of populations nearby of the springs′ catchment areas. Moreover, the urban expansion leads to increasing non-point source pollution with high effects on spring's′ water quality.

Therefore, in order to obtain the protection of the public health, it is essential to ensure water quality according to JS and WHO Guidelines for drinking-water quality. This is a strong motivation to lead this kind of study.

2. Study Area

NWSCA is located at the western part of Jordan, about 20 km northeast of the Dead Sea. It is located at 209-229 E and 144-165 N (according to Palestine grids) and covers a total area of approximately 185 Km^2 (Figure 1). A steep relief characterizes the area with elevations ranging from 1118 m above mean sea level (amsl) at El-Nabi Yousha′ to about 100 m below mean sea level (bmsl) at south Shoonah. The general shape of the catchment area is rectangular, with longer axis oriented NE-SW (Ta′any, 1992).

The study area is dominated by interstratification of karstic lime stones, marls and dolomites of the Upper Cretaceous Ajlun Group and lower part of the Balqa Group. Some main parts of the study area are intensively jointed and cut by faults (Figure 2). The joints are often enlarged by corrosion (Mikbel and Zacher, 1981).

In regard of the limestone of the formations, they are partially soluble in water and weak acid solution, thereby forming limestone pavements, potholes, centos, caves and gorges and then accelerating percolation rates to groundwater. Depending on the described geological situation, the vulnerability of groundwater is high.

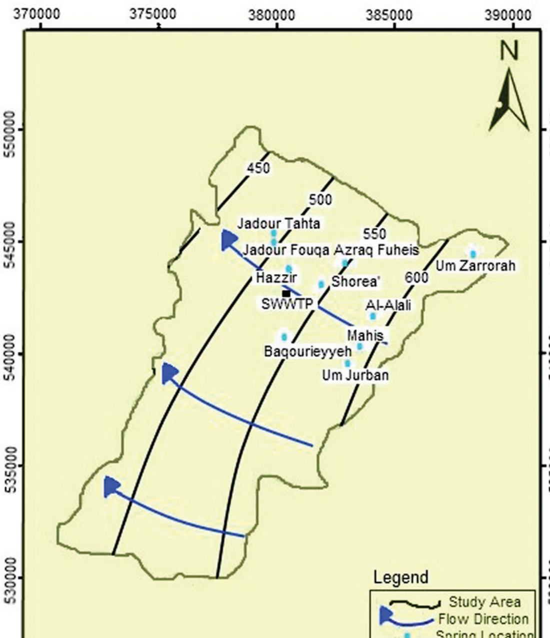

Figure 1: Locations of the studied springs and SWWTP in NWSCA and groundwater flow map of Wadi Shu′eib Catchment Area.

In some locations especially in Wadi Shu′eib area, intensive irrigation agriculture is possible during summer, whereas in the grabenshoulders, rain-fed agriculture exists. Because the Wadi Shu′eib watercourse itself has water all the year supplied by the outflow of the water treatment plant of Salt, some parts of the NWSCA have special crop situations. However, attention should be paid for the irrigation methods used in the study area, which are drip and subsurface irrigation systems (Salameh and Bannayan, 1993).

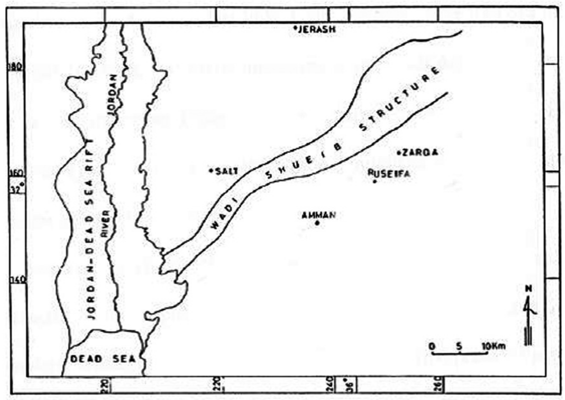

Figure 2: Location of the Wadi Shu'eib Structure (Werz 2006).

There are twenty-two major springs in the catchment area, nine springs emerge their water from Wadi Es-Sir Aquifer (A7), five from Hummar Aquifer (A4) and eight from Na′ur Aquifer (A1/2). Ten representative springs were selected for the purpose of this study. Figure (1) shows the locations of the selected springs and SWWTP in NWSCA. The discharge of these springs reaches to about 1000 (m3/hr) (Ta'any and Al-Kharabsheh, 2002).

The drainage path of the surface runoff follows the topography in NE-SW direction (Werz, 2006). However, the groundwater flow follows mainly the dipping of strata of the Na′ur, Hummar and Wadi Es-Sir aquifers separated by the lower permeability interstratifications of the Fuheis and Shu′eib formations as in Figure (2). Harter (2003) found that groundwater naturally flows at a speed that may range yearly from a few meters in poorly producing aquifers to a few thousand meters in very productive aquifers. However, in very sandy or gravelly aquifers and in some highly porous or cavernous volcanic and karstic aquifers, groundwater speed may be 3048 m per year or more.

According to Salameh and Bannayan (1993), the average natural flow of the wadi is 1.8 (MCM/year) as flood flow and 3.9 (MCM/year) as base flow. In addition to that, the effluent of the SWWTP, one of the best-functioning plants in Jordan, is discharged into the wadi. A dam was constructed in Wadi Shu′eib with a capacity of 2.3 MCM for irrigation purposes. Some parts of NWSCA, are located on the banks of Wadi Shu′eib course, have special crop situations due to supplementary water from the outflow of SWWTP during the year. At locations above the wastewater treatment plant and in the lateral valleys of the Wadi Shu′eib area mainly orchards exists.

Another two treatment plants are located in NWSCA; Fuheis and Mahis Wastewater Treatment plant, in addition to Fuheis Site SMART project. However, this study does not include them as a point of study because of low probability of pollution caused by these plants. More clarifications about both of them are within the context. The middle and northern parts of NWSCA are dominated by olive trees agriculture (Werz, 2006). Agriculture in the southern parts is limited to the existence of continuous soil cover. Built-up areas are mainly located in the northern and the northeastern areas that are characterized by a high population density, while sparsely populated parts are in the south of the study area. Open Files of the Department of Statistics of Jordan (2010) reported that the number of houses using septic tanks are 3664, 377 and 495 against 10474, 2208 and 1577 use sewer system; are serving 83202, 13171 and 12049 capita in the areas of Salt, Fuheis and Mahis, respectively. However, around 782 capita of

135 houses in Wadi Shu′eib totally use septic tanks systems. Consequently, 26%, 14.5%, 24% and 100% of population in Salt, Fuheis, Mahis and Wadi Shu′eib, respectively, depend on septic system to discharge their domestic wastewater.

According to the views at fieldwork, Hazzir, Shorea′, Baqouriyyeh, Mahis and Azraq Fuheis are used for drinking purposes and all of them are chlorinated by specialized parties. On the other hand, the springs of Um Jurban, Jadour Tahta and Um Zarrorah are used for drinking by residents without any kind of treatment. Jadour Fouqa spring is used for agricultural purposes and other domestic uses, but Al-Alai spring, which is under authority of Fuheis Cement Factory, is used for industrial purposes.

3. Materials and Methods

The examination of water quality is a determination of microorganisms, minerals and organic compounds contained in water. Physical analyses; pH and Electrical Conductivity, chemical analyses; major cations (Na^+, K^+, Ca^{2+} and Mg^{2+}), major anions (Cl^-, CO_3^{2-}, HCO_3^-, SO_4^{2-}, NO_3^- and PO_4^{3-}), heavy metals (Fe^{2+} and Pb^{2+}), Chemical Oxygen Demand (COD) and Biological Oxygen Demand (BOD), were carried out. Also biological analyses; total coliform as Most Probable Number (MPN) method were performed on springs water samples to determine their water quality.

The samples were taken before chlorination from ten representative springs in the study area as well as from the effluent of SWWTP. Samples were stored cool until analyses. The analyses of all parameters were carried out in the Laboratories of the Department of Water Resources and Environmental Management (DWREM) at the Faculty of Agricultural Technology, Al-Balqa′ Applied University, Salt, Jordan.

The samples were collected and analyzed on monthly basis for a whole year. Two thousand five hundred and eight analyses for nineteen parameters were carried out. The analytical techniques were performed according to the procedures mentioned in Standard Methods for the Examination of Water and Wastewater (Clesceri et al.,2005).

4. Results, Discussion and Conclusion

The average value of pH for the different springs ranges between 7.0 for Al-Alali and 7.5 for Shorea′, Um Zarrorah and Azraq Fuheis. Table (1) shows the average and standard deviation of all studied parameters of the representative springs and SWWTP in the study area. The pH value of Al-Alali spring confirms the existence of bicarbonate as a result of limestone dissolution. In all springs, the pH values are acceptable for drinking water according to JS and WHO Guidelines for drinking-water quality. According to Subramania classification (1997) of the pH, the water samples could be classified into two groups, the first is classified as springs of soft water including Jadour Fouqa, Jadour Tahta, Hazzir, Baqourieyyeh, Um Jurban, Al-Alali and Mahis springs and the second one as springs of hard water including Shorea′, Um Zarrorah and Azraq Fuheis spring.

The average value of Electrical Conductivity (EC) of springs′ water samples ranges between 540.3 (µS/cm) for Shorea′ spring and 1036.2 (µS/cm) for Al-Alali spring. According to JS and WHO Guidelines for drinking-water quality, all water samples are within the permissible limit of EC. High value of EC in Al-Alali spring confirms a high content of dissolved solids, which can be attributed to the leakage of sewer water from present or old septic tanks caused by the urban expansion along the recharge area of the spring. A considerable correlation is found between high concentrations of pollutants, come from seepage of sewer system such as Cl^- and Na^+, and the high value of EC of Al-Alali spring. The correlation coefficient values demonstrate a high positive relevance between them as 0.9745 and 0.9627, respectively. Whereas Shorea′ spring is located in an area surrounded by a few houses located faraway. Therefore, there are no continuous pollution sources near the recharge area of this spring and this may explain its low EC value. The addition of excess of agricultural fertilizers represented by the nitrogenous, phosphatic or organic fertilizers, to soil increases the value of leached chemical pollutants to springs′ water.

In Jordan there is a lack of information concerning fertilizers quantities, which are used and lead to potential groundwater hazards. Lists of number, type, location, and the size of industrial firms were not existing or available from public offices or ministries. This fact can be considered as normal for areas such as the study area. Precise and reliable information concerning infrastructural installations, such as wastewater, sewer systems or utilization ratio of streets, or the amount and nature of fertilizers or number of livestock in agriculture, is often difficult to obtain (Storz, 2004).

The average value of turbidity of the water samples ranges between 0.8 NTU for Jadour Fouqa, Mahis and Azraq Fuheis springs and 2.8 NTU for Hazzir spring. All springs have turbidity values within the permissible limit of JS and WHO Guidelines for drinking-water quality, except of Hazzir spring where two values in January and February were found out of the permissible limit. This may due to winter season rainfall that easily feed the Hummar formation where Hazzir spring emerges. During winter season, the high flow rate of leaked water through the formation of underground karstic limestone get the spring′s water to be turbid taking into account the dissolution process. Hence, once the rain reaches the ground, it passes through soil that can provide much more CO_2 to form a weak carbonic acid solution, which dissolves calcium carbonate as suspended matter causing turbidity of groundwater.

The average value of the total hardness of water samples ranges between 213 (mg/l) as $CaCO_3$ for Shorea′ spring and 392.9 (mg/l) as $CaCO_3$ for Al-Alali spring. All the studied springs have total hardness values within the permissible limit of JS and WHO Guidelines for drinking-water quality. The values of total hardness for both springs (Shorea′ and Al-Alali) agree with EC values, in addition to the positive relation between EC and dissolved metallic ions of calcium and magnesium (Shalash and Ghanem, 2008). A Significant correlation coefficient of 0.8926 is found between the EC and calcium values for both springs, which refer to a strong relation between the two parameters.

According to Freeze and Cherry classification (1979) of the total hardness, the water samples of springs can be classified into two groups; the first is hard water springs including Shorea', Azraq Fuheis and Baqourieyyeh and the second is very hard water springs including Um Zarrorah, Jadour Fouqa, Jadour Tahta, Hazzir, Um Jurban, Al-Alali, and Mahis. All concentrations of calcium are higher than magnesium concentrations for all springs. This is highly attributed to the dissolution of limestone that is mainly built of Ca-mineral.

The total alkalinity values of all examined springs are only represented by bicarbonate concentrations because pH values were less than 8.3. The average value of bicarbonate ranges between 179 (mg/l) for Shorea′ spring and 318.5 (mg/l) for Al-Alali spring. A positive relationship is found between EC

Table 1: The average and standard deviation of the analyzed parameters for the springs and SWWTP.

Analysis	Jadour Fouqa	Jadour Tahta	Hazzir	Shorea'	Baqourieyyeh	Um Jurban	Al-Alali	Mahis	Um Zarrorah	Azraq Fuheis
pH	7.4±0.2	7.4±0.2	7.2±0.2	7.5±0.2	7.3±0.2	7.2±0.2	7.0±0.2	7.2±0.2	7.5±0.2	7.5±0.2
EC (µs/cm)	934.6±13	944.9±11	895.8±34.8	540.3±19.9	674.9±34.1	988.2±13.6	1036.2±17.3	707.1±6.9	754.5±15.1	556.9±20.2
Turbidity (NTU)	0.8±0.4	1.5±0.5	2.8±2.5	1.8±0.9	1.2±0.9	1.7±0.9	1.4±1.5	0.8±0.6	0.9±0.7	0.8±0.7
Ca (mg/L)	94.9±6.1	98.9±8.6	101.5±12.3	66.4±7.1	80.8±4.1	121.6±11.2	137.3±14.6	88.2±4	103.1±13.6	70.9±3.8
Mg (mg/L)	22.2±4.6	17.9±4.3	16.9±4.3	11.5±4.2	15.9±6.2	17.0±2.4	12.2±3.5	21.4±6.1	11.5±5.7	13.4±2
T. H. as $CaCO_3$ (mg/L)	328±11.1	320.3±11.1	322.7±19.2	213±8.1	267±24.4	373.6±30.4	392.9±32.8	302.7±10.6	304.8±16.9	232.3±12.2
HCO_3^- (mg/L)	209±11.5	203.9±10.3	249.3±8.8	179±15.9	217.5±11.4	316.6±15	318.5±10	236.1±6.9	234.5±21.1	193±7.7
Cl^- (mg/L)	93.7±6	95.3±7.5	79.5±8	37.2±5.4	54.2±6.5	90±2.9	93.2±6.2	56.1±2.9	55.3±2.5	41.5±5.3
NO_3^- (mg/L)	95.8±12	103.7±17.9	73.2±20.1	30.2±9.9	33.6±4.2	58±10.2	46.5±3.3	35.5±5.9	61.6±9.4	27±6.9
PO_4^{3-} (mg/L)	0±0.1	0.1±0.1	0.7±0.8	0.1±0.1	0.1±0.1	0±0.1	0±0	0±0	0±0.1	0±0.1
SO_4^{2-} (mg/L)	33.5±7.3	27.2±10.7	25.4±3.2	16.2±8.5	25.2±7.1	27±7.3	59.8±8.3	24±5.3	28.7±7.1	20.3±4.1
Na^+ (mg/L)	42.7±6.1	40.5±6.7	33.8±6.1	15.6±5.8	22.8±6.8	45.6±13.3	51.9±9.4	20.7±3.5	23.3±7.9	19.1±3.6
K^+ (mg/L)	14.7±1.6	14.1±4.2	8.8±2.3	1.4±1.2	4.5±0.9	6.2±1.6	6.6±1.6	1.5±1.1	1.5±1.1	1.4±1.1
BOD (mgO_2/L)	26.5±18	25.3±16.3	29.3±17.6	26±17.9	23.8±16.4	27.7±16.6	27.8±18.4	25.8±19	28.3±17.4	16.1±16.3
COD (mgO_2/L)	45.7±29.7	42±27.4	51±30.2	42.5±28.6	41.8±29	48.1±27.8	48.4±29.3	42.6±32.2	48.5±26.1	23.8±27
T. Coliform (MPN/ 100 ml)	1008.4±920.1	1167.5±1386.7	2658.3±1815.8	678.3±793.8	133.3±39.2	721.7±605.7	1775±1123.4	120±193.6	11741.7±15000.4	10.1±8.2
Iron (mg/L)	0.1±0.1	0.2±0.1	0.1±0	0.1±0.1	0.1±0	0.1±0.2	0.1±0	0.1±0.1	0.1±0	0.1±0.1
Lead (mg/L)	0.1±0.1	0.1±0.1	0.1±0.1	0±0	0.1±0.1	0.1±0	0±0.1	0±0.1	0.1±0	0±0.1

and total alkalinity; hence, the highest value of bicarbonate of Al-Alali spring correlates with its highest value of EC. Furthermore, the lowest value of bicarbonate for Shorea′ spring accompanies with its lowest EC value. The relatively high values of bicarbonate for the springs are primarily due to the dissolution of limestone and marl of the region (Ta′any, 1992). All studied springs samples prove a high correlation between EC and bicarbonate values through a correlation coefficient value of 0.7111.

The average value of chloride ranges between 37.2 and 95.3 (mg/l) for Shorea′ and Jadour Tahta springs, respectively. Due to the effects of urbanization, the relatively high values of chloride for Jadour Tahta can be explained. The recharge area is contaminated by direct seepage of septic tanks or old sewer system. The dissolution of rocks and soils may also contribute in considerable amount of chloride constituents in the spring's′ water. All springs have chloride concentrations within the permissible limit of JS and WHO Guidelines for drinking-water quality. A significant correlation exists between chloride and sodium concentrations of spring's′ water of a correlation coefficient value of 0.9564. This indicates a high probability of wastewater as a source of contamination. It is well known, that septic tanks increase the risk of exceeding drinking criteria for nitrate and chloride. The higher is the nitrate content of a specific location, the higher is the chloride content of this location as found for Jadour Fouqa spring. A significant correlation exists between chloride and nitrate with a correlation coefficient equals to 0.8.

The average value of nitrate ranges between 27 (mg/l) for Azraq Fuheis spring and 103.7 (mg/l) for Jadour Tahta spring. Most of the springs have higher nitrate content during the months of February, March and April. This can be attributed to contribution of excess nitrogen fertilization and manure addition during the agricultural season. Jadour Fouqa, Jadour Tahta and Hazzir springs have high concentrations of nitrate exceed the JS and WHO Guidelines for drinking-water quality. These high concentrations indicate to high probability of presence of organic matter resulting from domestic wastewater or seepage from septic tanks. Particularly for Jadour Tahta spring, the partial disposal of Salt slaughterhouse in the catchment area of the spring can be regarded as a source of pollution. Management of groundwater quality in unsewered areas focuses on nitrate because it is the primary chemical of concern associated in septic systems. Nearly all nitrogen passing through the drain field converts to nitrate in the aerobic soil zone and eventually flow to the groundwater, especially through joints and faults of the Upper Cretaceous Limestone rocks (GWMAP, 1999).

Most of the studied springs have considerable concentrations of phosphate during the months of March, April and May, the period of soil fertilization. These are at Shorea′, Jadour Tahta and Baqourieyyeh springs which have phosphate average of 0.1 (mg/l) with a maximum average concentration of 0.7 (mg/l) for Hazzir spring. This relatively high value indicates an input of anthropogenic wastewater or agricultural fertilizer. Most phosphorous contained in the septic tank is in organic forms and mainly as orthophosphate (Wilhelm et al.,1994).

Koelle (2003) defined phosphate concentrations higher than 100 (μg/l) as a pollution indicator. According to that, Hazzir spring is polluted with phosphate but the following springs: Jadour Tahta, Shorea′ and Baqourieyyeh have the upper permissible limit of phosphate to still suitable for drinking water.

The average value of sulfate ranges from 16.2 (mg/l) for Shorea′ spring to 59.8 (mg/l) for Al-Alali spring. The sulfate composition is contained in groundwater because of chemical weathering of sedimentary rocks in the study area. Each of the springs has sulfate value within the permissible limit of JS and WHO Guidelines for drinking-water quality. The average value of sodium ranges from 15.6 (mg/l) for Shorea′ spring to 51.9 (mg/l) for Al-Alali spring. Relatively high concentrations may be found in brines and hard water and this explains the positive relation between total hardness (Ca^{2+} and Mg^{2+}), sodium and EC such as at Al-Alali spring as explained before. All springs have sodium values within the permissible limit of JS and WHO Guidelines for drinking-water quality.

The average value of potassium ranges between 1.4 (mg/l) for Shorea′ spring and 14.7 (mg/l) for Jadour Fouka spring. High values of potassium in Jadour Fouqa, Jadour Tahta and Hazzir springs can be attributed to the agricultural activities represented by the addition of the popular synthetic potassium nitrate fertilizers to soils used in the recharge areas of these springs. As an artificial plant supplement, KNO_3 is added for high-value crops. It is typically made by reacting potassium chloride with a nitrate source (IPNI, 2007). A significant correlation exists between the concentrations of nitrate and potassium of the three mentioned springs with a high considerable correlation coefficient value of 0.8992. However, all springs have potassium values within the permissible limit of JS and WHO Guidelines for drinking-water quality.

In the springs of Jadour Fouqa, Shorea′, Um Jurban, Mahis and Azraq Fuheis, iron was either not detected or under the detection value. The other springs have iron value of 0.1 (mg/l) which is still within the permissible limit of lead according to JS and WHO Guidelines for drinking-water quality. Upward and downward of Jadour Tahta, Hazzir, Baqourieyyeh, Al-Alali and Um Zarrorah springs catchment areas, there are pollution sources such as roads, where many drivers clean their cars using the spring′s unprotected water. In particular, for Jadour Tahta spring another pollution source is the slaughterhouse, which is closely located beside the catchment area of this spring. The permanent seepage output of animal blood residues can be observed on the soil surface. This definitely affects the water quality by raising the iron concentration of the spring′s water. We attribute the results, that the trace metal as iron is typically low in human waste (Wilhelm et al.,1994). Concentrations of trace inorganics may reach levels of concern in poorly buffered groundwater systems if the pH of groundwater samples is below than 6.0 (Robertson and Blowes, 1995). But this is not relevant for the present study, because pH samples′ readings ranged between (7.0 and 7.5).

Lead parameter values for Azraq Fuheis, Jadour Fouqa, Jadour Tahta, Hazzir, Baqourieyyeh, Mahis, Shorea' and Al-Alali springs were either not detected or under detection. However, lead values of 0.1 (mg/l) were detected for Um Jurban and Um Zarrorah springs and exceed the maximum allowable limit according to JS and WHO Guidelines for drinking-water quality.

The average value of COD ranges between 23.8 (mg/l) for Azraq Fuheis spring and 51.0 (mg/l) for Hazzir spring. Although Azraq Fuheis spring has the minimum value of COD it has to be considered as high value because of their use for drinking water abstraction. The COD value of drinking water should be less than 10 (mg/l) (WAJ Open Files, 2010). This high values could be attributed to the occasional disposal of wastewater tanks and seepage of agricultural wastewater that penetrate within the Wadi Es-Sir Limestone (A7) formation then reach the groundwater. The relative low value of Azraq Fuheis spring compared with other springs is assigned to the spring′s location. Only this spring is surrounded in two directions by a few faraway houses. In comparison, Hazzir spring showing the highest COD value is close to urban expansion in its catchment area. Um Zarrorah, Al-Alali and Um Jurban springs that have catchment areas crossed with existence of septic tanks show high values of COD. The high COD values of Jadour Fouqa are caused by a lack of sewer system and the close urbanization to the springs catchment area. The pollution sources for other springs are variant. For Jadour Tahta, the presence of slaughterhouse near to its catchment area increases the probability of pollution resulted from cleaning high-polluted slaughtered equipments by spring′s water, in addition to throwing some slaughter wastes adjacent to its catchment area. According to Chan (2001) and Benka and Ojior (1995), a positive relation between the relatively high COD and BOD values with high values of NO_3^- and total coliform is a decisive indicator for the exposure to source of organic pollutant. Shorea′ and Baqourieyyeh springs are facing the same pollution source represented by the occasional disposal of wastewater tanks. However, Mahis spring also faces the effect of presence of old and present septic tanks in its catchment area.

The average value of BOD ranges between 16.1 (mg/l) for Azraq Fuheis spring and 29.3 (mg/l) for Hazzir spring. Drinking water should have BOD value less than 5 (mg/l) (WAJ Open Files, 2010). However, all BOD results of springs exceed 5 (mg/l). This indicates a high probability of presence of organic matter resulting from domestic wastewater seepage from septic tanks or decaying of agricultural residues. The joints and faults present in the Upper Cretaceous Limestone rocks that cover the catchment area of the springs accelerate the penetration rate of these objects to reach groundwater.

The average value of total coliform ranges from 10.1 (MPN/100 ml) for Azraq Fuheis spring to 2658.3 and 11741.7 (MPN/100 ml) for Hazzir and Um Zarrorah springs, respectively. All springs have total coliform values exceed the permissible limit according to JS and WHO Guidelines for drinking-water quality. These values are caused by contamination with total coliform from septic tanks wastewater seepage to the spring’s′ sources. Furthermore, storm water runoff during high stream flow, which is often called non-point source pollution, contributes to groundwater quality problems. About 80% of houses within the borders of Fuheis Municipality have been connected with the sewer system (Fuheis Municipality, 2010), only 65% for Mahis Municipality (Mahis Municipality, 2010), whereas in Salt Municipality is 78% (Salt Municipality, 2010). Faecal coliforms analyses were not performed in this study, however, total coliform persistence may refer to faecal origin, (Edberg et al.,1998).

Most prominent factors that affect the recharge area of the springs are the informal settlement or irregular urbanization and unplanned land use around the recharge areas of the springs. This is accompanied by absence of primary services such as sewer system. Furthermore, high slope of the catchment area accelerates the pollution rate along the recharge area of the springs. Moreover, the geological formation of the Upper Cretaceous Limestone rocks covers the catchment area of the springs, also increases the pollution rate due to the presence of joints, faults and massive cliffs through it.

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