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Preliminary Environmental Assessment of the Pollution of Soil and Water at Wadi Uranah, Makkah Al-Mukarramah, Saudi Arabia

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ABSTRACT. The environmental impact of sewagewater effluent discharged into the lower part of Wadi Uranah, Makkah Al-Mukarramah area on soil and underground water was evaluated. Water samples from the stream and the adjacent wells, in addition to soil samples from the wadi and the stream were collected. Chemical analysis and bacterial examinations for stream wastewater, contaminated well water, stream polluted soil and wadi unpolluted soil were performed. Physical properties for soil samples were also determined.

The results of chemical analyses revealed that, the values of most of the tested elements are higher in wastewater than in well water except for pH, Ca, Mg, Fe, Cl, Ni, Cr, and Cu. It was also found that, the BOD, COD, NO_3 and the heavy metals such as Zn, Mn, Cu, Ni, Pb, Cr and Cd, in the tested wastewater, are higher than the permissible standard limits, in addition to the presence of huge quantities of infectious bacteria. The amount of Zn, Pb and NO_3 in the wastewater and polluted soil are extremely high. Sewagewater was found more contaminated than the well-water. Furthermore, the values of Ca, Mg and PO_4 are higher in the wadi soil than the polluted soil.

The study indicates that, the sewagewater and the well water, in their present condition, are not suitable and unhealthy for human consumption or domestic and irrigation purposes. This situation was due to the presence of high concentration of organic materials, salts, heavy metals and bacteria. The study results also indicated that the treated wastewater in the stream is unfit for direct discharge and reuse. The farms should be prevented from the use of wastewater either directly or from the contaminated wells.

Introduction

The wastewater is known as the accumulated water after being used for different purposes at homes, commercial or industrial works in addition to the flood water which flows through the cities and passes through polluted agents such as solid waste disposed materials, oils or/and food remnants. It contains several solid or dissolved elements of which the water represents a ratio of about 99%. Sewagewater contains suspended materials, undecayable organic materials, heavy minerals, soluble mineral salts, infectious organisms and nutritive materials for plants such as nitrogen, phosphorus, potassium, and decayable organic materials. The major biological contaminants in wastewater include pathogenic bacteria, viruses and parasites. They create serious health problems such as typhoid fever, cholera, polio and hepatitis. The number of infectious organisms depends on the type of used water and the processes, which the water has undergone during treatment (Nebel & Wright, 1993).

Wastewater is disposed on or below the ground surface in different ways. The septic tanks used in many countries in the world contribute into groundwater contamination. In the United States, only one third of the population is disposing off their domestic wastewater through sewage systems. The surface disposal of sewage is extensive in the third world countries in rural, recreational and suburban areas (Henry and Heinke, 1989).

There are very serious environmental, economical and social impacts relating to the groundwater contamination resulting by wastewater discharge and an urgent remedial action is a must in such a case. The temporary solutions are costly even if they seem to be cheaper in the short term when compared with the permanent solutions.

The wastewater is a major cause of environmental and health problems if not treated well due to the presence of different kinds of viruses, bacteria, other organisms, and high concentrations of chemicals. If such water is used for agriculture activity some of the chemicals might accumulate and endanger the soils and the plants. If on the other hand, it infiltrates into the ground, the fresh groundwater will be contaminated (Henry & Heinke, 1989). The problem of contamination has attracted the attention of researchers in the last three decades. Domenico and Schwartz (1990) claim that the main source of biological contamination of groundwater is from human and animal sewage or wastewater originated from sewage or septic tanks, leachates from sanitary landfills or various agricultural practices.

The heavy elements, which are present in the wastewater may include cadmium, copper, chrome, lead, mercury, nickel, zinc, aluminum, antimony, arsenic, magnesium and selenium. The concentration of these pollutants differ from place to another according to their surrounding conditions. The phosphate is concentrated in the wastewater due to the use of cleaners. Although the phosphate minerals are important for the nutrition of plants, however their higher concentrations adversely effect the environment. Higher amounts of phosphate concentration can be absorbed by soil, specially the clayey alkali soils, and may activate the growth of fungi and water born grasses on the account of other organisms which effect the ecosystem balance. The soluble materials in the wastewater might be accumulated and concentrated to a limit which will cause soil saltation, especially that this water is also rich with nitrates, chlorides, sodium, calcium, magnesium, phosphorus and other elements (Appleton *et al.,* 1996).

Several studies on the effect of wastewater on the characteristics of soil and ground water were carried out by Abdl-Elnaim *et al.* (1982); Behel *et al.* (1983); Dowdy and Vork (1988); Mehmood and Igbal (1995); Chettri and Smith (1995); Appleyard (1996); Tarchitzky *et al.* (1999); Weng and Xunhong (2000) and Friedel *et al.* (2000). Other studies were conducted to evaluate the presence of heavy metals by Moore and Ramamoorthy (1983); Fergusson (1990); El-Hassanin *et al.* (1992); Hirschberg (1993); Lottermoser (1998) and Basamad (2001).

Makkah Al-Mukarramah, like other cities in the Kingdom of Saudi Arabia, suffers from the problem related to the wastewater treatment and disposal as it drained into the neighboring wadis such as Wadi Uranah (Fig. 1). The study area is located between Latitudes 21º21′ and 21º29′ and Longitudes 39º45′ and 39º47′ 5 km south of Makkah Al-Mukarramah (Fig. 2). In 1995, during normal days, about 25,000 to 35,000 m^3 of wastewater is treated daily at Al-Kakiah station. This quantity is increased during Ramadan and Hajj seasons to about 80,000 m^3/day. The treated water is discharged into the south western wadis. The discharge of the wastewater effluent into the down stream section of wadi Uranah (Fig. 3) had begun before the year 1984 and contaminated until now creating a perennial stream flowing towards the Red Sea crossing Taif/Jizan Road. At the end of May 1997 the wastewater stream reached a length of 37.5 km from the treatment station. Camels, herds of sheep and wild birds have a free access to the stream (Fig. 4). Wild weed and vegetation are growing on the banks of the stream. Organic matters precipitate during over-flooding on the banks of the stream.

A reconnaissance study has been made at the down stream section of wadi Uranah, south of Makkah Al-Mukarramah (Al-Rehaili and Bankher, 1998). The groundwater level has risen from a depth of 17 m from the ground surface, to a

FIG. 1. Photograph showing the main outlet of the wastewater disposal to an open stream at Wadi Uranah.

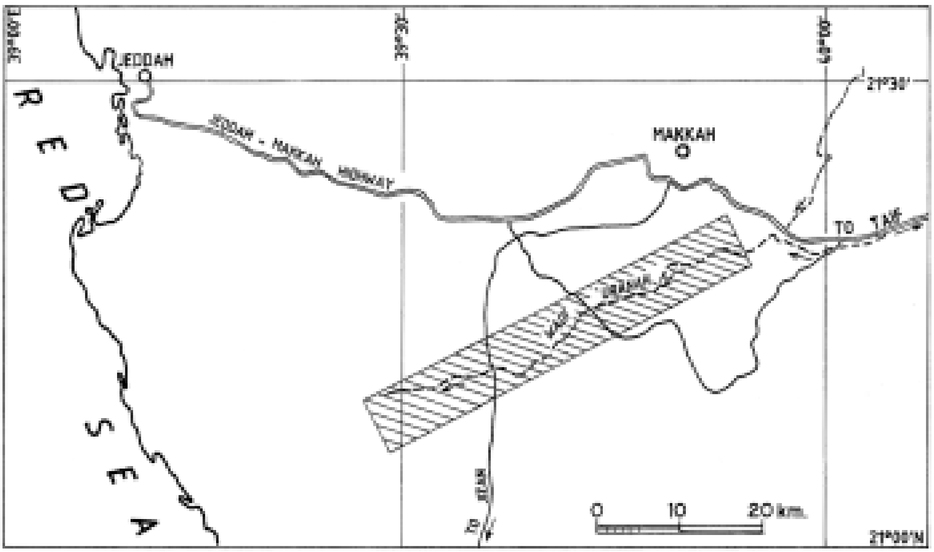

FIG. 2. Location map of the study area.

FIG. 3. Photograph showing the wastewater stream along the wadi.

FIG. 4. Photograph showing the animals grazing around the wastewater stream.

depth of 5 m, which ultimately encouraged the establishment of commercial and agricultural activities in the area. The study indicated that the water in the area is microbiologically polluted and can't be used for human consumption. However, due to the high concentration of salts it is anticipated that this water will also become unsuitable for agriculture purposes with time. Detailed studies are needed in order to determine the impact of this polluted water on the environment. Therefore, the purpose of this study has been oriented towards the assessment of the environmental hazards associated by the disposal of wastewater into wadi Uranah.

Geology and Geomorphology

Geologically the studied area consists of basement rocks and unconsolidated sediments (Fig. 5). The basement rocks consist of igneous extrusive rocks such as andesite and porphyritic andesite and from igneous plutonic rocks which include microgranite, diorite, quartzdiorite, gabbro and quartz gabbro. These rocks were intruded by some dykes, and are cut by strike slip faults which have orientations that coincide with the orientation of the wadis in the area (Moore and Al-Rehaili, 1989). The unconsolidated sediments include coarse gravel, gravelly sand and silty sand. They had been accumulated as a product of erosion and weathering of the surrounding rocks and/or transported as wadi sediments by flood action.

Wadi Uranah extends in the southwestern direction with several large tributaries draining into it, such as wadi Naman and wadi Al-Sharai. The upstream

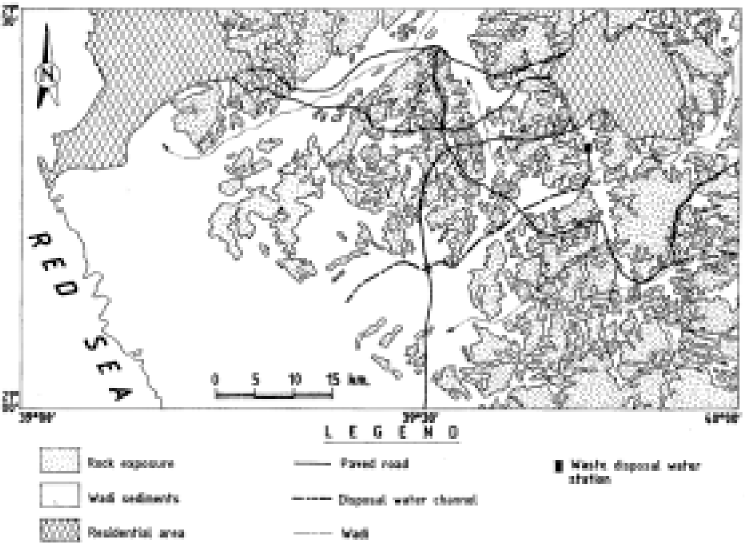

FIG. 5. Geologic map of the study area and the surrounding.

section of wadi Uranah where the agriculture activity is concentrated can be considered as one of the sources of water for Makkah Al-Mukarramah City and the Holy places. The down stream section of the wadi shows no agriculture activity due to the presence of high salinity and less quantity of water. The level of the groundwater table has risen sharply since the disposal of the wastewater started in the area.

Methods of Investigations

Sampling Program

Wadi Uranah could be subdivided into five sections along the stream route from which five wastewater samples, five polluted soil samples and five unpolluted soil samples were collected. In addition, three well water samples, from the existing wells along the wadi were also collected (Fig. 6). Two liters capacity plastic containers were used to collect the wastewater and well water samples. The wastewater was taken at a depth of 10 cm below the water surface of the stream to avoid the floating materials, while the well water was collected during pumping. The soil samples were collected at a depth ranging between 0 and 30 cm. They were air dried, crushed, sieved through a 20-mesh sieve, mixed thoroughly and stored for laboratory analysis.

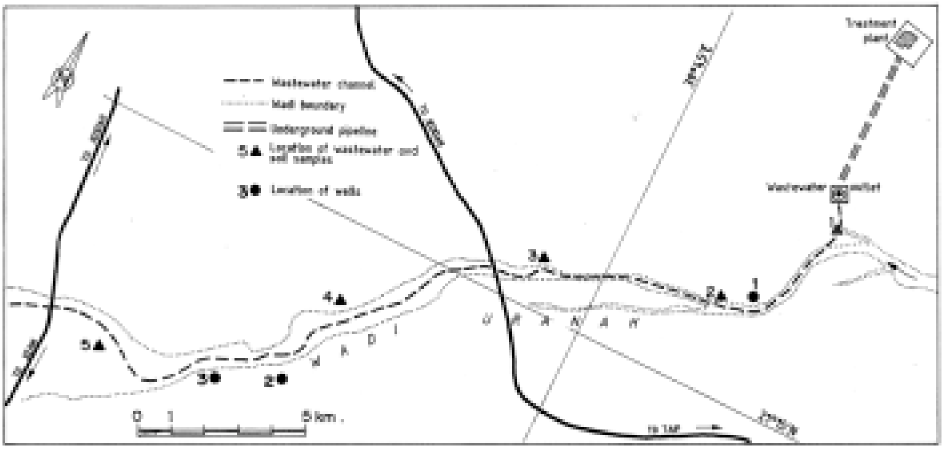

Fig. 6: An index map showing the sampling locations in the study area.

Wastewater samples for microbiological investigations were also collected from the five stream sections and the water wells. One liter capacity sterilized glass containers were used. Containers were immediately closed and kept in ice-box until they were transported to the laboratory for analysis. Efforts were made to ensure the best water sample representation from each stream section and water well.

Testing Program

The polluted and unpolluted soil samples were tested for their physical properties. These included the grain size distribution (ASTM D422-63), specific gravity (ASTM D854-92), moisture content (ASTM D2216-92), and liquid limit, plastic limit and plasticity index (ASTM D4318-93) in addition to color and odour. The collected soil samples and water samples were also tested for total hardness (TH), total dissolved salts (TDS), pH, electric conductivity (EC), NO_3, PO_4, macronutrients such as Ca, Mg, Na, Fe, K, Cl and heavy metals such as Zn, Mn, Cu, Ni, Pb, Cr and Cd. The biological oxygen demand (BOD) and the chemical oxygen demand (COD), expressed in 100 milligrams per liter, were determined for all the water samples. The standard methods that were used in the examination of the water are given in (AWWA, 1995a,b and c).

Results

Physical and Chemical Properties of Polluted and Unpolluted Soil

The grain size distribution (Fig. 7) indicates that the wadi unpolluted soil is poorly graded sand with silt, while the stream polluted soil is poorly graded, non-plastic silty sand with minor clay. The soil samples were classified according to the Unified Soil Classification (Terzaghi and Peck 1968) as poorly graded sand and silty sand (SP) .Generally, the percentage of sand and silty materials are higher in the wadi soil than in the polluted soil by about 6% and 2% respectively. The clay content is relatively higher in the polluted stream soil.

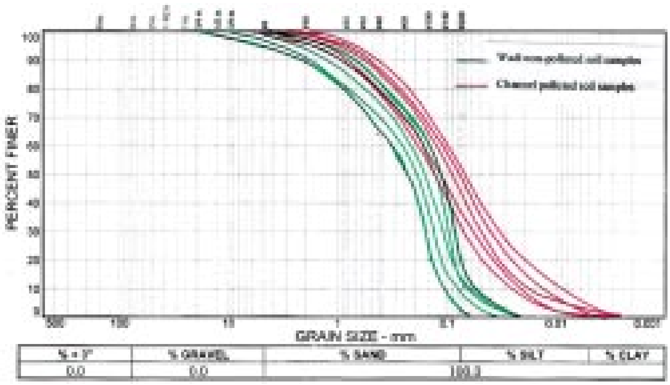

FIG. 7. Grain size distribution curves of the studied polluted and unpolluted soil samples.

The physical properties of the polluted and unpolluted soil samples are given in Table 1. The color of the wadi unpolluted soil is yellowish brown with no odour, whereas the color of the stream polluted soil is dark brown with bad odour (Fig. 8). The calculated average specific gravity of the polluted soils ob-

TABLE 1. Results of some physical properties of stream polluted and unpolluted wadi soil samples.

Sample type	Sample no.	Gradation (%)			Physical properties						
		Sand	Silt	Clay	Color	Odour	Specific gravity	Cu	Cc	Moisture content (%)	Liquid & plastic limits
Stream polluted soil	1	88.6	6.3	5.1	Dark brown	Bad	2.44	2.13	1.01	38.7	non-plastic
	2	86.2	5.4	8.4	Dark brown	Bad	2.43	2.18	0.83	29.0	non-plastic
	3	87.5	5.2	7.3	Dark brown	Bad	2.41	2.24	0.90	40.5	non-plastic
	4	83.7	6.5	9.8	Dark brown	Bad	2.42	2.51	1.00	37.2	non-plastic
	5	85.4	5.0	9.6	Dark brown	Bad	2.43	2.37	0.79	42.3	non-plastic
	Range average	(83.7-88.6) 86.28	(9.3-12.5) 5.68	(5.1-9.8) 8.04	Dark brown Dark brown	Bad Bad	(2.41-2.44) 2.43	(2.13-2.51) 2.29	(0.79-1.01) 0.91	(29.0-42.3) 37.54	– non-plastic
Wadi unpolluted soil	1	92.5	7.5	0.0	Yellowish brown	No	2.54	2.32	1.08	0.8	non-plastic
	2	93.2	6.8	0.0	Yellowish brown	No	2.55	3.54	0.76	2.3	non-plastic
	3	91.1	8.9	0.0	Yellowish brown	No	2.52	2.31	1.02	1.7	non-plastic
	4	92.6	7.4	0.0	Yellowish brown	No	2.56	2.47	1.05	2.1	non-plastic
	5	93.8	6.2	0.0	Yellowish brown	No	2.48	3.85	0.92	1.8	non-plastic
	Range average	(91.1-93.8) 92.64	(2.9-7.5) 7.36	0.0 0.0	Yellowish brown Yellowish brown	No No	(2.48-2.56) 2.53	(2.32-3.85) 2.90	(0.76-1.08) 0.97	(0.8-2.3) 1.74	– non-plastic

tained from the sewage stream ranges between 2.41and 2.44 with an average of about 2.43. These values are lower than those of the unpolluted wadi soils obtained from the wadi, which range between 2.54 and 2.57 with an average of about 2.53. The difference between these specific gravity values could be due to the presence of 8% of the clayey materials in the polluted soil. The average values of C_u and C_c for the polluted stream soils are 2.29 and 0.91 respectively and 2.90 and 0.97 for the unpolluted wadi soils. These values are higher for unpolluted wadi soil than those of polluted stream soil. Based on the values of C_u and C_c (Table 1), the unpolluted wadi soil was classified as moderately well sorted, while the polluted soil was classified as moderately sorted.

FIG. 8. Photograph showing the difference between the polluted and unpolluted soil from the study area.

The results of the chemical analyses of the tested soils (Tables 2 and 3; Figs. 9, 10 and 11) show that the polluted stream soil has relatively very high concentrations of NO_3, TH, TDS, Cl, Zn, Mn, Cu, Ni, Pb, Cr and Cu and very low pH values with an average of 5.5. The wadi unpolluted soil is richer in Ca, Mg and PO_4 elements.

TABLE 2. Results of chemical analysis (major elements) of stream polluted and unpolluted wadi soil samples.

Sample type	Sample no.	TH (mg/liter)	TDS (mg/liter)	EC us/cm	pH	NO_3 (mg/liter)	PO_4 (mg/liter)
Stream polluted soil	1	952	2106	2620	6.1	521.8	0.65
	2	935	1275	1865	6.3	128.3	1.03
	3	1121	2835	3125	5.4	549.1	0.58
	4	989	1498	1889	5.2	98.5	0.89
	5	1005	1418	2032	4.6	215.7	1.01
	Range average	(935-1121) 1000	(1275-2835) 1826	(1889-3125) 2306	(4.6-6.3) 5.51	(98.5-521.8) 302.7	(0.58-1.03) 0.83
Wadi unpolluted soil	1	785	1115	1635	7.6	43.8	1.82
	2	714	1221	2123	7.2	51.4	1.35
	3	617	1058	1354	7.8	6.1	1.49
	4	606	947	1325	7.3	29.7	2.21
	5	587	1140	1927	7.5	24.1	1.76
	Range average	(587-785) 722	(947-1221) 1096	(1325-2123) 1673	(7.2-7.8) 7.5	(6.1-51.4) 31.0	(1.35-2.21) 1.73

Sample type	Sample no.	Ca (mg/liter)	Mg (mg/liter)	Na (mg/liter)	Fe (mg/liter)	K (mg/liter)	Cl (mg/liter)
Stream polluted soil	1	146.1	13.6	72.1	1.9	318.6	1025
	2	20.5	2.4	38.6	2.5	125.5	950
	3	35.6	29.3	187.1	1.7	29.1	1997
	4	49.3	38.4	102.3	1.8	85.3	1115
	5	83.4	65.1	67.2	2.2	72.9	895
	Range average	(20.5-146.1) 67.0	(2.4-65.1) 29.8	(38.6-187.1) 93.5	(1.8-2.5) 2.0	(29.1-318.6) 126.3	(895-1997) 1196.4
Wadi unpolluted soil	1	201.7	75.3	37.9	1.0	27.1	718
	2	153.1	120.1	13.4	0.7	66.2	802
	3	272.0	113.5	45.0	0.8	13.5	592
	4	102.9	95.1	9.1	0.9	6.3	680
	5	183.2	62.7	18.6	1.2	83.7	745
	Range average	(102.9-272.0) 182.6	(62.7-120.1) 93.4	(9.1-45.0) 24.8	(0.7-1.2) 0.9	(6.3-83.7) 39.4	(592-745) 707.4

TABLE 3. Results of heavy metals analysis of stream polluted and unpolluted wadi soil samples.

Sample type	Sample no.	Zn (mg/liter)	Mn (mg/liter)	Cu (mg/liter)	Ni (mg/liter)	Pb (mg/liter)	Cr (mg/liter)	Cd (mg/liter)
Stream polluted soil	1	2.4	0.5	0.09	0.8	3.6	0.31	0.008
	2	3.8	0.5	0.10	0.5	2.7	0.09	0.009
	3	1.5	0.8	0.08	0.7	2.9	0.26	0.008
	4	4.1	0.6	0.12	0.8	3.3	0.39	0.010
	5	3.7	0.5	0.14	0.8	3.7	0.31	0.007
	Range average	(1.5-4.1) 3.1	(0.5-0.8) 0.6	(0.08-0.14) 0.11	(0.5-0.8) 0.75	(2.7-3.7) 3.3	(0.09-0.39) 0.27	(0.007-0.010) 0.009
Wadi unpolluted soil	1	0.9	0.2	0.01	0.005	< 0.05	< 0.05	< 0.005
	2	0.4	0.3	0.00	0.097	< 0.05	< 0.05	< 0.005
	3	0.6	0.1	0.09	0.006	< 0.05	< 0.05	< 0.005
	4	1.2	0.1	0.03	0.007	< 0.05	< 0.05	< 0.005
	5	0.9	0.1	0.05	0.090	< 0.05	< 0.05	< 0.005
	Range average	(0.4-1.2) 0.8	(0.1-0.3) 0.2	(0.00-0.09) 0.04	(0.005-0.097) 0.04	< 0.05 < 0.05	< 0.05 < 0.05	< 0.005 < 0.005

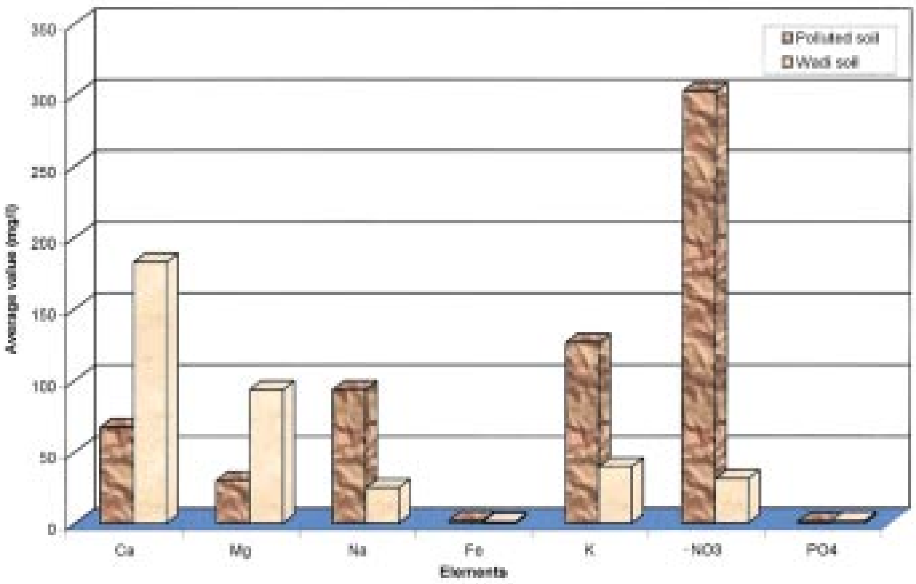

FIG. 9. Comparison of major chemical elements of polluted and unpolluted wadi soils.

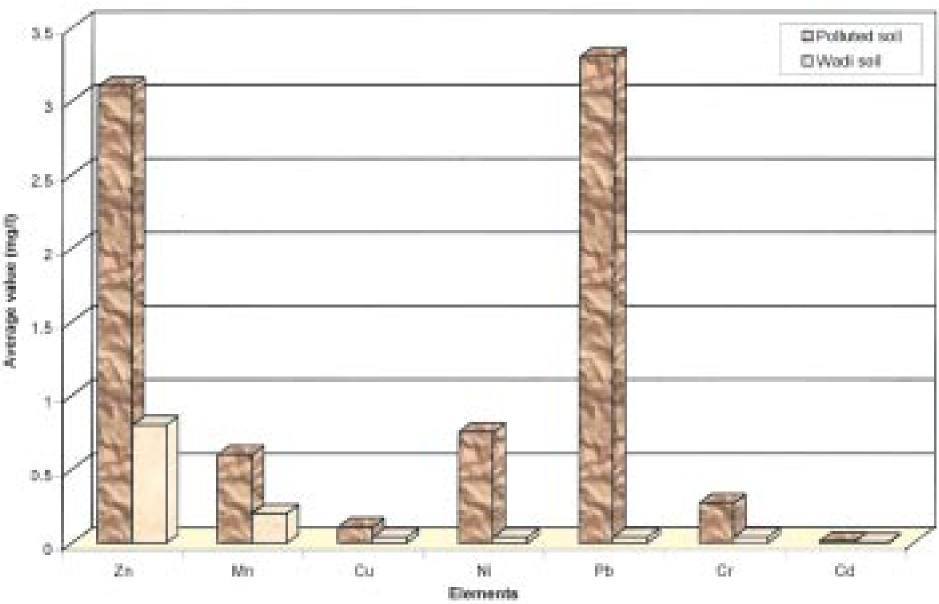

FIG. 10. Comparison of heavy metals of polluted and unpolluted wadi soils.

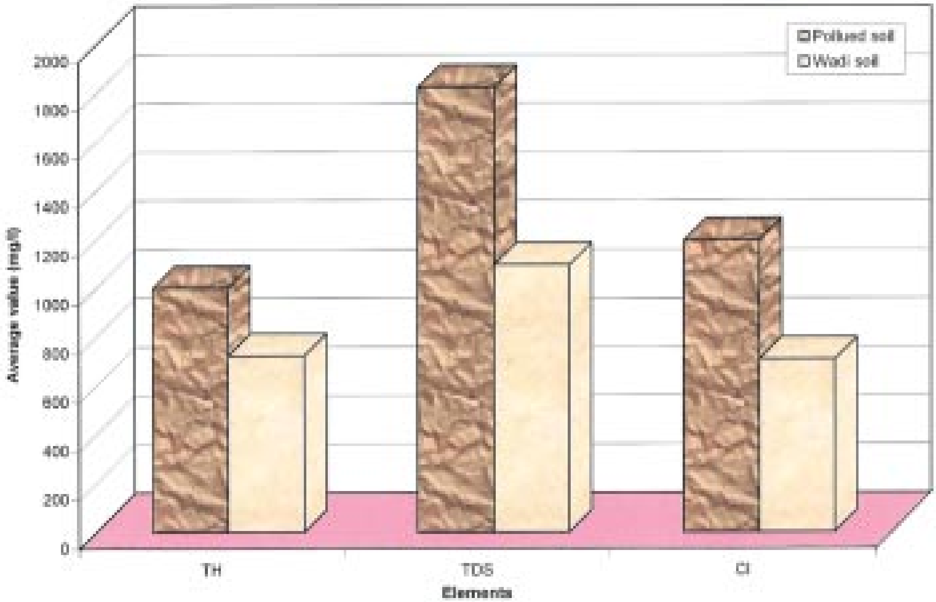

FIG. 11. Comparison of some trace elements of polluted and unpolluted wadi soils

Chemical and Biological Analysis of Wastewater and Well Water

The values of NO_3, PO_4, TH, TDS, Zn, Mn and Pb are high in the stream wastewater (Tables 4 and 5; Figs. 12, 13 and 14) with a very low pH value of about 6.0. The well water is rich in Ca, Mg and Fe elements with very high amount of Cl and minor amount of Cu, Ni, Cr and Cd. On the basis of the results, the well water is also considered to be slightly contaminated because the NO_3 value exceeds 10 mg/l according to WHO (1993) and MAW (1988) for both drinking water and for irrigation respectively.

The total hardness (TH) and the total disssolved solids (TDS) of the sewage and wells waters increase towards the downstream, which is possibly due to the increase in the Calcium (Ca) and Magnesium (Mg) contents leached from the soil. The nitrates (NO_3), which is considered as a pollution indicator, also increased in the wastewater towards the downstream and at the wells close to the stream.

All of the samples, which had been collected from the wastewater stream and wells, contain bacteria as shown in Table 6 and Fig. 15. The BOD value for the wastewater stream ranges between 81 mg/l and 111 mg/l with an average of 99 mg/l, while the COD value ranges between 92 mg/l and 145 mg/l with an average of 126 mg/l. The BOD value for the well water ranges between 18 mg/l and 24 mg/l with an average value of 21 mg/l, and the COD value ranges between

Table 4. Results of chemical analyses (major elements) of wastewater from the stream contaminated wells water.

Sample type	Sample no.	TH (mg/liter)	TDS (mg/liter)	EC us/cm	pH	NO_3 (mg/liter)	PO_4 (mg/liter)
Stream wastewater	1	501	797	1401	6.5	139	44.0
	2	522	832	1580	6.2	186	39.2
	3	585	993	1624	6.3	245	43.6
	4	731	939	1638	5.7	205	48.5
	5	688	968	1617	5.4	256	46.3
	Range average	(501-731) 605	(797-993) 906	(1401-1638) 1572	(5.4-6.5) 6.0	(139-256) 206	(39.2-48.5) 44.3
Contaminated well water	1	257	768	852	7.9	26.5	0.02
	2	235	603	1018	7.7	18.4	0.03
	3	249	663	890	7.8	23.1	0.02
	Range average	(235-257) 247	(603-768) 678	(852-1018) 920	(7.7-7.9) 7.8	(18.4-26.5) 22.7	(0.02-0.03) 0.023

Sample type	Sample no.	Ca (mg/liter)	Mg (mg/liter)	Na (mg/liter)	Fe (mg/liter)	K (mg/liter)	Cl (mg/liter)
Stream wastewater	1	70.0	15.8	283.6	1.1	26.8	175.0
	2	74.6	16.4	294.4	1.7	26.6	163.0
	3	74.6	19.5	321.5	2.3	29.3	195.2
	4	74.2	20.2	314.3	2.2	33.4	198.5
	5	72.2	21.5	318.6	2.2	28.0	171.3
	Range average	(70.0-74.6) 73.1	(15.8-21.5) 18.7	(283.6-321.5) 306.5	(1.1-2.3) 1.9	(26.6-33.4) 28.8	(163.0-198.5) 180.6
Contaminated well water	1	152.7	51.7	135.2	4.6	14.6	352.8
	2	110.3	38.6	104.6	5.7	16.3	246.4
	3	132.6	46.2	168.5	5.1	14.2	234.7
	Range average	(110.3-152.7) 131.9	(38.6-51.7) 45.5	(104.6-168.5) 136.1	(4.6-5.7) 5.2	(14.2-16.3) 15.0	(234.7-352.8) 278.0

TABLE 5. Results of heavy metals analyses of wastewater from the stream and contaminated wells water.

Sample type	Sample no.	Zn (mg/liter)	Mn (mg/liter)	Cu (mg/liter)	Ni (mg/liter)	Pb (mg/liter)	Cr (mg/liter)	Cd (mg/liter)
Stream wastewater	1	11.5	0.5	0.8	0.5	3.6	0.2	0.002
	2	13.8	0.5	0.6	0.3	2.7	0.2	0.003
	3	16.1	0.8	0.8	0.5	2.9	0.2	0.003
	4	9.8	0.6	0.8	0.5	3.3	0.3	0.004
	5	10.3	0.5	0.7	0.4	3.7	0.2	0.003
	Range average	(9.8-16.1) 12.3	(0.5-0.8) 0.6	(0.6-0.8) 0.77	(0.3-0.5) 0.4	(2.7-3.7) 3.3	(0.2-0.3) 0.2	(0.002-0.004) 0.003
Contaminated well water	1	5.7	0.3	1.7	0.7	2.5	0.4	0.005
	2	4.5	0.1	1.8	0.6	2.7	0.3	0.003
	3	1.3	0.1	1.8	0.6	2.4	0.4	0.004
	Range average	(1.3-5.7) 3.8	(0.1-0.3) 0.2	(1.7-1.8) 1.8	(0.6-0.7) 0.6	(2.4-2.7) 2.5	(0.3-0.4) 0.4	(0.003-0.005) 0.004

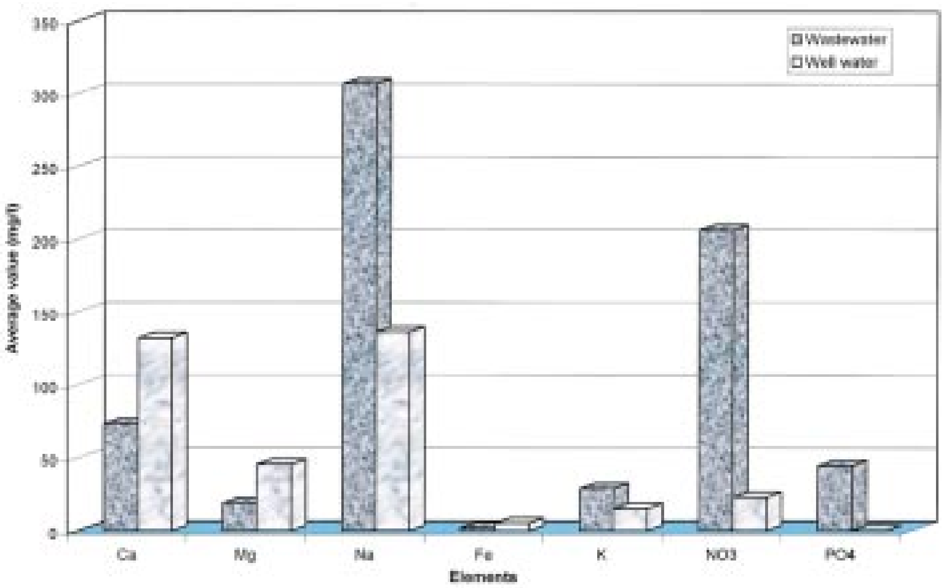

FIG. 12. Comparison of major chemical elements of wastewater and well water.

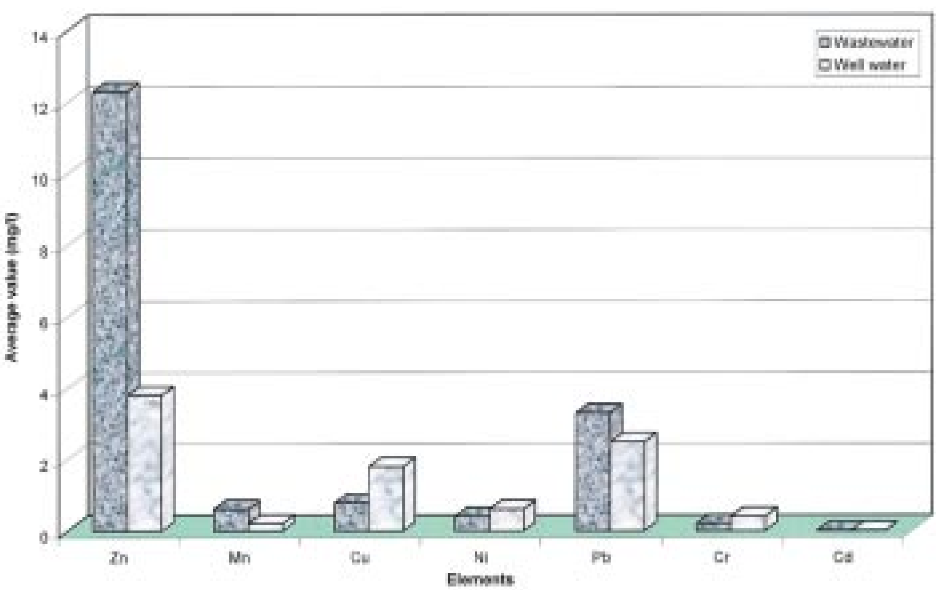

FIG. 13. Comparison of heavy metals of wastewater and well water.

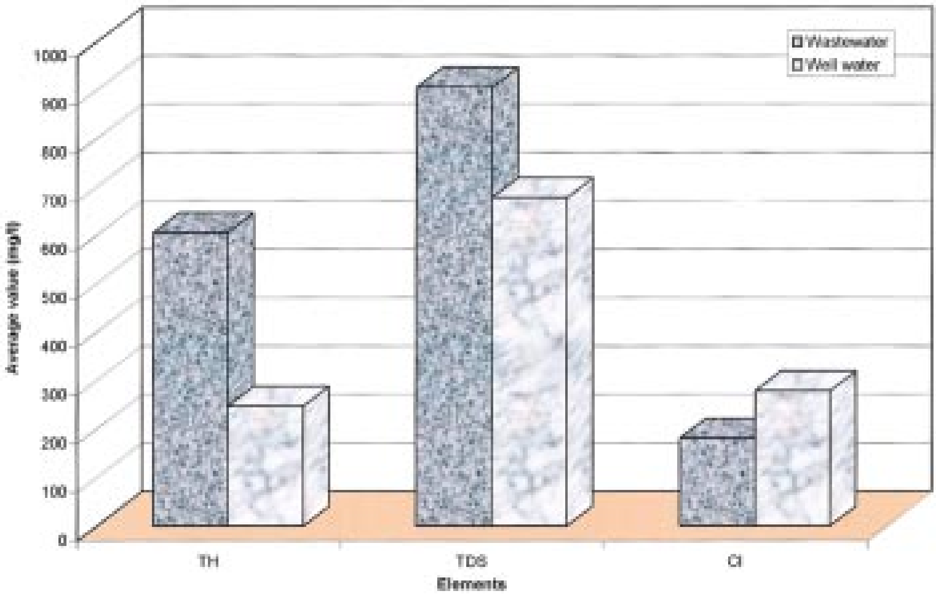

FIG. 14. Comparison of some trace elements of wastewater and well water.

TABLE 6. Results of organic and microbiological analyses of the stream wastewater and the well water samples.

Sample type	Sample no.	Total bacterial count (per 100 ml)	BOD (mg/l)	COD (mg/l)
Stream wastewater	1	400	81	115
	2	617	96	92
	3	518	107	154
	4	632	111	123
	5	783	102	147
	Range average	(400-783) 590	(81-111) 99	(92-154) 126
Contaminated well water	1	92	18	18
	2	58	21	32
	3	114	24	26
	Range average	(58-114) 88	(18-24) 21	(18-32) 25

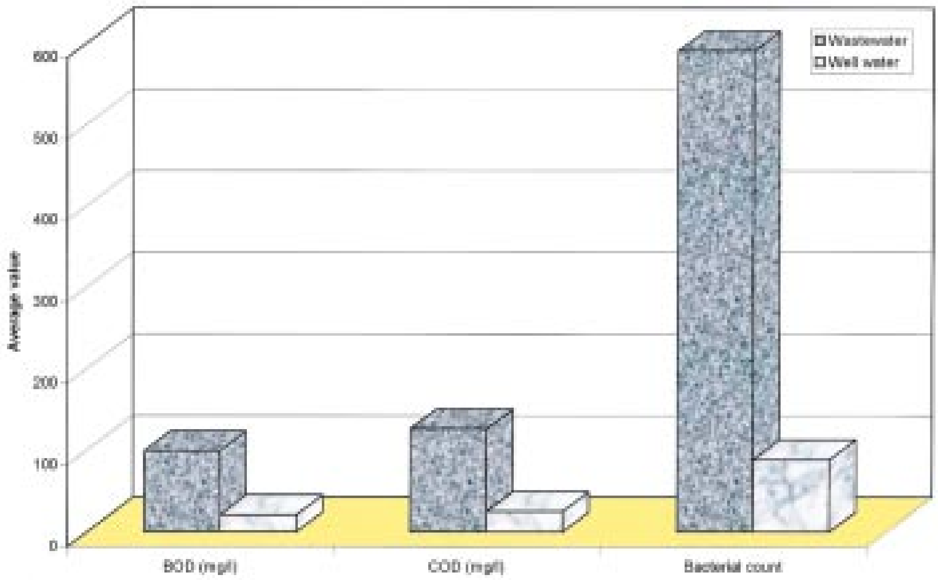

FIG. 15. Comparison of BOD, COD and total bacterial count of wastewater and well water.

18 mg/l and 32 mg/l with an average value of 25 mg/l. These results indicate that, both the surface and groundwater are biologically contaminated. The total bacterial count ranges between 400 per 100 ml and 783 per 100 ml with an average value of 590 per 100 ml for the wastewater and between 58 per 100 ml and 114 per 100 ml with an average value of 88 per 100 ml for the well water. The cause of the lowest quantity of coliform is considered to be due to the use of chlorine as a disinfictant before discharging of the sewagewater effluent into the stream.

The stream wastewater could be classified, according to Lloyd and Heathcote (1985), as sodium chloride rich (Na Cl), while the well water as sodium-calcium chloride rich (Na-Ca Cl) (Table 7) and both are of poor quality. The salt concentration may increase with time if the situation remains as it is and the well water will become completely unsuitable for irrigation purposes.

A comparison was made between the results of the water chemical and biological analyses and those of the permissible values suggested by SASO (1991) and WHO (1993) for drinking water and FAO (1985), MAW (1988) and MEPA (1989) for irrigation water (Table 8). It can be suggested that the wastewater flowing in the stream is not suitable for both human consumption or irrigation purposes due to the presence of high amount of BOD, Mn, Ni, Pb, Cr, Cd, Fe, TH, PO_4 and NO_3 in addition to low value of pH. The wells water is also unsuitable for human consumption due to the presence of high amount of Mn, Cu, Ni, Pb, Cr, Cd and Fe. It has a conditional suitability for agriculture purposes and precaution should be taken into consideration when ever it is used because of the organic pollutants, which are higher than the the permissible limits.

TABLE 7. Chemical composition of the stream wastewater and the well water samples and their suitability for general use.

Sample type	Sample no.	Water facies	Potability
Stream wastewater	1	NaCl	Poor
	2	NaCl	Poor
	3	NaCl	Poor
	4	NaCl	Poor
	5	NaCl	Poor
Contaminated well water	1	Na-CaCl	Poor
	2	Na-CaCl	Poor
	3	Na-CaCl	Poor

Discussion

Sewage Water

The result of this study showed a serious infringement with the standards set by the Meteorology and Environmental Protection Agency (MEPA, 1989) for the direct discharge of wastewater. Most of the elements analyzed during this study have however exceeded the compared standards (APHA, 1985; FAO, 1985; WHO, 1989 and 1993; MEPA, 1989 and SASO, 1991). These elements are Mn, Ni, Pb, Cr, Cd, Fe, TH, PO_4 and NO_3. The pH value was below the required standards. Only Zn, Cu, Ca, Mg, TDS and Cl were below the compared standards.

The microbial examinations of wastewater samples collected from the different locations from the discharged stream revealed a significant difference in the BOD and COD values, as well as the total bacterial counts. The seasonal temperature differences during the year may be partially responsible for these observed variations. Another reason for these observed differences may be related to the increased activities in the Holy places in Makkah Al-Mukarramah during Ramadan and Haj season. From the microbiological point of view, different recommendations were made to provide guidelines for microbial suitability of wastewater to be used for agriculture purposes. The prime objective in treating wastewater for utilization in agriculture is the removal of the microorganisms to prevent its health-associated effects.

TABLE 8. Comparison between the results of biological and chemical analyses of the stream wastewater and the contaminated wells water and the acceptable limits for drinking water and irrigation water.

Elements which affect health and taste (mg/liter)	Specification for drinking water		Specifications for irrigation water		Results of this study	
	Saudi Arabia Standards Organization (SASO) (1991)	World Health Organization of Europe (WHO) (1993)	Saudi Arabia Ministry of Agriculture and Water (MAW) (1988) & (MEPA, 1989)	Food and Agricultural Organization (FAO) (1985)	Contaminated well water	Stream wastewater
BOD	25	–	20	20	21	99
COD	150	–	–	–	25	126
Zn	15	5	4.0	2.0	3.8	12.3
Mn	0.5	0.1	0.001	0.2	0.2	0.6
Cu	1.5	1	0.02	0.1	1.8	0.8
Ni	0.05	0.05	0.05	0.2	0.6	0.4
Pb	0.1	0.05	1.0	5.0	2.5	3.3
Cr	0.05	0.05	0.1	0.1	0.4	0.2
Cd	0.001	0.005	0.02	0.01	0.004	0.003
Ca	200	–	–	400	131.9	73.1
Mg	150	–	–	60	45.5	18.7
Na	–	200	–	900	136.1	306.5
Fe	1	0.3	5.0	5.0	5.2	1.9
K	–	–	–	–	15.0	28.8
Cl	600	250	–	–	278.0	180.6
TH	500	500	–	–	247	605
TDS	1500	1000	10000-20000	–	687	906
EC (us/cm)	–	–	–	3000	2420	1572
pH	8.5	6.5-8.5	6.0-8.4	6.5-8.5	7.8	6.0
NO_3	45	10-45	10	–	22.7	206
PO_4	–	–	–	–	0.023	44.3

Well Water

The TDS in the three wells monitored had shown slight increase towards the downstream of the stream. The TDS, however, was slightly higher in the wastewater stream than in the wells water. This could be due to the low efficiency of the present wastewater treatment plant and the direct discharge of untreated wastewater to the wadi.

The overall mean concentration of Mn, Cu, Ni, Pb, Cr, Cd and Fe in the three wells' water render this water unfit for unrestricted irrigation. These values exceeded the limits of most of the compared standards during this investigation. The average values of BOD and NO_3 are found close to the standard limits.

The effect of the wastewater stream on the wells in its surrounding (effect of location) was most distinct in the salt contents of the water of these wells (TDS). The wells nearer to the stream showed higher TDS than those located away indicating a higher recharge of the former than the latter. Similar trends, but less distinct, were shown by Mg, Mn and Na. The other elements investigated indicated no specific trends in their concentrations in the wells' water according to their location around the stream. Only Cu, Ni and Cr showed higher concentrations in the wells' water than the stream wastewater.

From the microbiological point of view, the well water can be used for agriculture purposes for both restricted and unrestricted irrigation according to the standard limits given by Ministry of Agriculture and Water in Saudi Arabia (MAW, 1988) and Food and Agriculture Organization (FAO, 1985).

Soil

The continuous water flow of the sewage stream for more than twenty years did not change the texture class of the wadi's soil. However, it increased the percentage of clay and decreased the percentage of sand over the unpolluted soil. The prolonged period of wastewater stream flow has increased the organic matter, soil EC, soil content of NO_3, PO_4, Zn, Mn, Ni, Cu, Cr, Cd, Pb K, Na, Mg and Fe over the unpolluted soil. However, the soil pH, soil content of Ca and Mg decreased over the unpolluted soil.

Environmental Assessment

The concentrations of Mn, Ni, Pb, Cr, Cd, TH, TDS, PO_4 and NO_3 in the sewagewater exceeds the safe limits for the domestic use of the water. The presence of these toxic elements in the irrigation water causes their accumulation in the plant tissues and gets introduced to food chain. The accumulation of these elements in vegetables and other field crops may represent a real health problem. Therefore, care should be taken in using such water in irrigation. Efforts should also be made to prevent animals from drinking this water. The wells' water in the study area is also slightly contaminated and not potable because of its high salinity and also because it contains some toxic elements.

A serious infringement with the local and international standards was found for the direct discharge of the wastewater to the wadi. The vegetable and crop farms should be prevented from the use of the stream wastewater or the contaminated wells' water for the irrigation in order to conserve the general health. The animals must also be prevented from grazing or drinking the water in the area for health reasons. The environmental effects of using the wastewater in irrigation at Wadi Uranah were recognized from the quality and the apperance of the plants and the grasses (Fig. 16).

Fig. 16. Photograph showing the effect of wastewater on the plants and the surrounding environment.

The efficiency of the present wastewater treatment plant should be improved by increasing their capacities and adding a third treatment cycle in order to benefit from this water as much as possible. The wastewater discharged into the Wadi Uranah should be prevented from reaching the coastline of the Red Sea, and the possible contamination of both the land and the marine environments.

Conclusion

The chemical analysis of the water samples taken from the flowing stream and the water wells, indicate that, the water is classified as a sodium chloride rich (NaCl) for the wastewater and a calcium-magnesium chloride rich (CaMgCl) for the wells' water. If the saltation increases further, the wells' water will become unsuitable for irrigation purposes. The concentration of Cr, Cu, Mn, Ni, Pb and Zn in both the wastewater and wells' water exceed the safe limit of both Saudi Arabia (MAW, 1988 and SASO, 1991) and FAO (1985) standards. The wastewater also contains huge quantities of infectious bacteria and has a very high BOD and COD values

The stream wastewater is unsuitable for human use due to the high concentration of organic materials, salts, heavy metals, minerals and bacteria. Although the well water is also unsuitable for human consumption, it has conditional suitability for agricultural purposes. Precautions should be taken into account as its contamination and pollution is higher than the permissible values. The wadi soil along and close to the wastewater stream is completely polluted and contains high values of NO_3, TH, TDS, Cl, Zn, Mn, Cu, Ni, Pb, Cr and Cu with very low pH values. This type of soil is not suitable for agricultural purposes.

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التقييم البيئي المبـدئي لتلوث التربـة والمـاء بـوادي عرنـة مكة المكرمة – المملكة العربية السعودية

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المستخلص . تم القيام بدراسة مبدئية للتأثير البيئي نتيجة تصريف مياه الصرف الصحي في الجزء السفلي لوادي عرنة بمكة المكرمة وذلك على التربة والمياه الجوفية. وقد جمعت عينات الماء من قناة الصرف الصحي والآبار المجاورة ، بالإضافة إلى عينات التربة من الوادي ومن القناة. حيث تم القيام بعمل التحاليل الكيميائية والفحوصات البكتيرية على مياه الصرف الصحي ومياه الآبار المجاورة وتربة القناة الملوثة وتربة الوادي السليمة ، وكذلك إيجاد الخصائص الفيزيائية لعينات التربة .

وقد أوضحت نتائج التحاليل أن نسب معظم العناصر التي فحصت عالية في مياه الصرف الصحي عن مياه الآبار ، ما عدا الأس الهيدروجيني ، الكالسيوم ، المغنيسيوم ، الحديد ، الكلور ، النيكل ، الكروميوم والنحاس . ووجد أن نسب تواجد المتطلب الأكسوجيني الحيوي *BOD* والمتطلب الأكسوجيني الكيميائي *COD* والنترات ، بالإضافة إلى العناصر الثقيلة مثل الزنك، المغنيز النحاس، النيكل، الرصاص، الكروميوم والكادميوم أعلى من النسبة المسموح بها في المواصفات لتصريف مياه الصرف الصحي ، زيادةً على وجود نسب عالية من البكتيريا الممرضة . كما وجد كذلك أن عناصر الزنك والرصاص والنترات في مياه الصرف الصحي والتربة الملوثة من القناة عالية جداً. ومن ذلك فقد اتضح أن مياه الصرف الصحي المتدفقة في القناة ومياه الآبار ملوثة . وأن قيم عناصر الكالسيوم والمغنيسيوم والفوسفات عالية في تربة الوادي عن تربة القناة الملوثة .

وقد بينت الدراسة أن مياه الصرف الصحي في القناة ومياه الآبار في

حالتها الحالية غير صالحة للاستهلاك الآدمي وغير مناسبة للأغراض المنزلية والزراعية وذلك لإحتوائها على تراكيز عالية من المواد العضوية والأملاح والعناصر الثقيلة والبكتيريا . كما أثبتت نتائج الدراسة أن مياه الصرف الصحي المعالجة في القناة غير مطابقة لتفريغها المباشر في الوادي واستخدامها . وعليه فيتوجب منع المزارعين من الاستخدام المباشر لمياه قناة الصرف الصحي أو مياه الآبار الملوثة في المنطقة .