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EVALUATION OF GROUNDWATER AND TREATED SEWAGE EFFLUENT QUALITY FOR IRRIGATION IN SAUDI ARABIA

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ABSTRACT

Comparative study was conducted to evaluate the quality of secondary treated sewage effluent (TSE) and groundwater of Riyadh region. Water samples from each type of water were collected from three sites at the four different seasons. EC of groundwater was significantly higher than TSE. Ca^{2+}, Mg^{2+}, Na^{+}, Cl^{-}, HCO_3^{-} of groundwater was significantly higher than TSE. Both irrigation waters had low amount of NH_4^{+} - N, NO_3^{-} - N, Fe, Mn, Zn, and Cu which below the levels recommended for water quality. Bacterial populations of Daryiah and Waseel sites did not show any significant differences, however, their counts were significantly higher in Ammaryah site. There were no significant differences between groundwater and TSE in their content of bacteria, although TSE contained higher numbers of bacteria than groundwater has. Fungal counts were significantly higher at Daryiah site as compared with the other sites. In contrast, the highest density of streptomycetes was recorded at Waseel site. Fungal and streptomycetes counts were significantly higher in groundwater than TSE. Results also revealed that different microbial groups differed inconsistently between sites, seasons and irrigation type. The highest most probable numbers of different groups were found in TSE as compared to groundwater (1.3 to 22 fold higher than groundwater). Microbial communities appeared to be differed between sites where nitrifiers and sulfate reducers were found in high density at different sites than the other groups of microorganisms. Conversely, the density of denitrifiers and N_2-fixers were significantly higher at Daryiah site than the other sites. Sulfate-reducers showed their highest density at Waseel site. Treated sewage effluent of Riyadh region has a good quality for irrigation and did not show any deleterious effects as compared to groundwater. Due to the presence of fecal coliform in this effluent which is used as indicators of sewage pollution, it can be safely used for irrigation the wood trees, forests and landscape.

Keywords: Treated sewage effluent, groundwater, water quality, microbial populations

INTRODUCTION

Ground water is the main irrigation water resource in Saudi Arabia. Due to the rapid growth of irrigated agriculture and high technology of drilling wells, the rate of water withdrawal from wells has increased. This over exploitation of the different wells may lead to severe water shortage for agriculture in future. At the same time the quality of water will be changed. According to Kadaj (1991), a prominent desalination expert and international consultant in advanced water technology, water will be the dominant resource issue of the Middle East. Therefore, wastewater reclamation and reuse in agriculture has received considerable attention around the world especially in arid and semi-arid regions (Halpenny, 1973, Badr, 1984 and Arab Water World, 1991).

The suitability of sewage effluent as irrigation water and groundwater recharge largely depends on its physico-chemical characteristics and on the microbial load it contains. Comparing the physico-chemical composition of the effluent with the quality standards for underground native irrigation water, and evaluating the occurrence of microorganisms in the effluent against criteria that have been formulated by public health agencies, will indicate what crops could be irrigated with the effluent depending on the extent of treatment before utilization.

During the last two decades an attention has been focused by the Ministry of Agriculture and Irrigation, Saudi Arabia on utilization of the municipal sewage effluent for industrial and agricultural purposes especially outside the boundaries of the large cities such as Riyadh, Jeddah and Madena and in both Al-Qassim and Eastern regions. Al-Ogaily *et al.* (1999) reported that 418 million m^3 of sewage water (approximately 100 million m^3 of treated sewage effluent from Riyadh city) is potentially available annually which is expected to increase proportionally with the rapid urbanization. Badr (1984) indicated that the treated wastewater might make a valuable contribution to the scarce water resources. He estimated the volume of recycled water in Al-Qassim, Saudi Arabia around 2 million m^3 by the year 2000. Halpenny (1973), Madancy (1981), Bouwer and Rice (1981), Arab Water World (1991) reported that wastewater reclamation and reuse in agriculture has received much attention around the world especially in arid and semi-arid regions. Abdel-Magid (1996) stated that electrical conductivity (EC) and pH values of sewage effluent in Al-Qassim region, Saudi Arabia are within the acceptable limits and are not expected to cause severe problems. He also added that high total coliform count ($4.8 \times 10^3 - 1.4 \times 10^5$ MPN 100 ml^{-1}) was evident in spite of achieving between 99.92 – 99.96 % mean removal efficiency.

The quality of irrigated water is dependent on total concentration of soluble salts (salinity), concentration of sodium relative to other cations (sodicity), anion composition of the water and concentration of boron and the other elements that may be toxic to plant growth (Shainberg and Oster, 1978). Ayers and Westcot (1985) demonstrated that the suitability of water for irrigation is determined not only by the total amount of salt present but also by the kind of salt. The salts are applied with the water and remain behind the soil as water evaporates or are used by the crop. They also added that the quality is defined by certain physical, chemical and biological characteristics. Al-Omran (1987) indicated that the dominant cation and anion are Ca^{2+} and SO_4^{2-} in water samples collected from wells in the central region of Saudi Arabia. El-Arabi *et al.* (1996) indicated that irrigation, using mostly secondary treated sewage effluent, has been introduced on new land reclamation projects in sandy areas of eastern and western fringes of Nile Delta, Egypt. Alaa-El Din *et al.* (1993) found that salt concentration from 388 wells in six regions in Saudi Arabia varied widely from 180 to 9350 mg l^{-1} and pH values were in the range from 5.9 – 8.8.

This work is aiming at evaluating two main sources of water to be used for the agricultural irrigation purposes in Saudi Arabia. The study focused on the physicochemical properties and microbial populations of groundwater (GW) and treated sewage effluent (TSE).

MATERIALS and METHODS

Sampling:

Two main sources of water were used i.e. groundwater (GW) and municipal secondary treatment sewage effluent (TSE) from Riyadh pumping station (Riyadh Domestic Sewage Treatment Plant). Water samples (three replicates) were collected from three sites situated in Riyadh region at about 40 km north-east down town (56.2°N, 33.8°E). The sites were, Daryiah, Waseel and Ammaryah. The samples were taken during four seasons (October 1998, April 1999, August 1999 and February 2000 which represented Autumn, Spring, Summer and Winter, respectively). Representative irrigation water samples from different localities of each site (groundwater and TSE) were collected in sterilized bottles (500 ml capacity). The samples were transported at the ambient temperature directly after collection to the laboratory and analyzed abruptly for microbial, physical and chemical properties.

Physical and chemical analyses

The water samples collected from the various sites were analyzed for electrical conductivity (EC,dS m^{-1}), pH, soluble cations (Ca^{2+} , Mg^{2+} , Na^{+} and K^{+}), soluble anions (CO_3^- , HCO_3^-,Cl^-, and SO_4^{2-}), NH_4^+ and NO_3^- (Rhoades, 1982). Organic matter (Mebius, 1960), total nitrogen (Bremner and Mulvancey, 1982), total phosphorus (Olsen and Dean, 1982), total $CaCO_3$ (using standard calcimeter procedure, Black, 1965) and heavy metals (Fe, Mn, Zn,and Cu) were determined using Perkin Elmer Model 2380 Atomic Absorption Spectrophotometer (AAS). Some toxic heavy metals (Pb, Cd and Cr) were also determined in groundwater and TSE by AAS (Perkin Elmer Analyst 300) using graphite furnace technique. Sodium adsorption ratio (SAR) was estimated according to Ayers and Wescot (1985). All analyses were carried out in the laboratory of Soil Science Department, College of Agriculture, King Saud University, Riyadh, Saudi Arabia.

Microbiological determinations:

Different microbial populations were determined in both groundwater and TSE samples. Plate count technique was followed for determination of total bacteria, streptomycetes and fungi using specific media for each group according to Benson (1985), Kuster and Williams (1964) and Jacobs and Gerstein (1960), respectively. Free aerobic nitrogen fixers (non-symbiotic diazotrophs), nitrifying bacteria, denitrifiers, sulfate-reducers and sulfur-oxidizers were counted using dilution frequency method (Most Probable Number, MPN) according to Abdel-Malek and Ishac (1968), Bodelier *et al.* (1998), Abdel-Malek *et al.* (1974), Meynell and Meynell (1970) and Brock (1979), respectively. Multiple-tube fermentation and Millipore techniques (WHO, 1984) were used to detect the coliform in irrigation water. Biochemical oxygen demand (BOD) was determined in groundwater and TSE using Dissolved Oxygen Meter, Model 9300, Jenway Limited, England. Dissolved oxygen was estimated at initial time and after 5 days of incubation at 20°C as recommended by APHA (1967), and BOD_5 was calculated.

Statistical analysis:

Statistical analyses were performed using SAS (1985). Analysis of variance for interaction of irrigation type with seasons, sites with irrigation type and sites with seasons was carried out by two-way ANOVA (at 5 % probability level) to test whether there were significant differences between sites, seasons and irrigation type. Correlation coefficient (r) was also estimated.

RESULTS and DISCUSSION

Electrical conductivity and pH values:

Data in Table, 1 show that electrical conductivity (EC) of irrigation water was significantly affected by source of irrigation. EC of groundwater was significantly higher than that observed for TSE where its values ranged from 1.61 to 2.9 (mean = 2.25) dS m^{-1} against 1.30 to 1.65 (mean = 1.44) dS m^{-1} for sewage water. Alaa-El Din *et al.* (1993) stated that salt concentration from 388 wells in six regions in Saudi Arabia varied widely from 180 to 9350 mg L^{-1} (EC = 0.28 to 14.61 dS m^{-1}). The sewage water is mostly of desalinated origin and does not contain discharges from industrial wastewater or other wastes. This is clearly explaining the low values of salinity in such type of water. These results are in line with those observed by Abdel-Magid (1996) who observed that electrical conductivity values of sewage effluent of Al-Qassim region, Saudi Arabia are within the acceptable limits and are not expected to cause problems.

Table(1): Electrical conductivity and pH value of ground and sewage water as affected by site and season.

Seasons	pH		E.C (dS m^{-1})	
	GW	TSE	GW	TSE
Daryiah				
Summer	7.47	8.41	2.50	1.40
Autumn	8.38	7.05	2.00	1.35
Winter	7.53	6.61	2.90	1.58
Spring	8.13	7.57	2.34	1.41
Waseel				
Summer	7.83	8.08	2.17	1.36
Autumn	8.07	7.72	2.00	1.30
Winter	7.07	7.73	2.50	1.58
Spring	7.77	7.96	2.12	1.41
Ammaryah				
Summer	7.73	6.78	2.40	1.47
Autumn	8.02	7.56	1.61	1.47
Winter	6.96	7.28	2.65	1.65
Spring	7.45	7.90	1.86	1.37
LSD (at 0.05)				
Site (St)	0.88		0.99	
Season (Sn)	1.02		1.15	
Water (Wt)	0.72		0.81	
St*Sn*Wt	2.49		2.82	

With respect to the effect of sites on electrical conductivity, irrigation water from the different sites did not show any significant differences. The irrigation water gave the highest figure of EC in winter season which was significantly higher than the other seasons. The pH values of both irrigated water were slightly varied (Table 1). Statistical analysis revealed that the pH values of irrigation water at Waseel site were significantly higher than Ammaryah.

Soluble cations and anions:

Seasonal and spatial variations in soluble cations of irrigation water were noticed (Table 2). Generally the highest Ca^{2+} and Mg^{2+} cations were detected at Daryiah site, whereas the lowest values were obtained at Waseel site. In autumn season, Ca^{2+} was recorded in a high significant value compared to other seasons; thereafter its value was gradually decreased during season's succession registering insignificant differences. In contrast to that, Mg^{2+} cation showed the highest peak in winter season where its concentration was significantly higher than the recorded values in the other seasons. Na^{+} was significantly higher at Waseel site than the other two sites. During three seasons (summer, autumn and winter) Na^{+} did not show a significant difference while its concentration was significantly lower in the spring season. K^{+} cation did not show any significant differences among the three sites during the four seasons where its concentrations was approximately constant. Ca^{2+}, Mg^{2+} and Na^{+} were highly affected by source of irrigation water showing significantly higher amount in groundwater of different sites compared to TSE from the same sites. In contrast K^{+} was significantly lower in groundwater than TSE.

Table(2): Cation concentrations (mg L^{-1}) of ground and sewage water as affected by site and season.

Seasons	Cation concentration (mg L^{-1})							
	Ca^{++}		Mg^{++}		Na^{+}		K^{+}	
	GW	TSE	GW	TSE	GW	TSE	GW	TSE
Daryiah								
Summer	7.95	4.1	10.15	3.65	6.5	5.8	0.14	0.34
Autumn	10.0	5.45	7.30	2.05	4.37	3.65	0.13	0.35
Winter	8.5	4.1	12.07	7.15	5.75	5.35	0.15	0.23
Spring	6.95	4.7	9.25	2.3	6.5	3.9	0.14	0.36
Waseel								
Summer	5.7	3.85	8.2	3.45	8.4	6.7	0.10	0.39
Autumn	7.4	5.3	6.75	2.15	6.2	5.6	0.11	0.39
Winter	5.25	3.5	8.59	4.15	8.1	6.3	0.22	0.34
Spring	6.3	4.45	7.1	2.45	8.35	6.1	0.10	0.37
Ammaryah								
Summer	7.6	4.25	8.8	3.45	6.9	6.1	0.15	0.38
Autumn	12.05	5.05	6.95	2.1	5.2	4.2	0.15	0.35
Winter	5.5	3.5	11.75	7.35	6.51	6.1	0.14	0.38
Spring	7.6	4.25	5.65	2.48	6.87	5.0	0.13	0.36
LSD (at 0.05)								
Site (St)	1.79		3.23		1.27		0.46	
Season (Sn)	2.07		2.73		2.27		0.53	
Water (Wt)	1.45		2.64		0.86		0.14	
St*Sn*Wt	8.08		9.14		5.07		1.30	

Soluble anions of irrigation water are presented in Table (3). Soluble chloride of irrigation water was significantly higher at Daryiah site than the other two sites. The chloride concentration of groundwater at the different sites is considered to be slight to moderate for surface and sprinkler irrigation. In contrast, chloride concentration of TSE is in the usual range of irrigation water according to Ayers and Westcot (1985). Bicarbonate anion recorded the lowest concentration among the different sites comparing to other anions In contrast, the concentration of sulfate did not show any significant difference at the different sites. It was also found that the highest significant value of chloride was detected at autumn season, whereas the highest significant values of sulfate and bicarbonate were noticed at winter season. On the other hand, groundwater contained a considerable amount of chloride and bicarbonate (significantly different) compared to TSE (approximately 1.5-fold higher). However, sulfate did not show significant differences between the two sources of irrigation water.

Table 3: Anion concentrations (mg L^{-1}) of ground and sewage water as affected by site and season.

Seasons	Anion concentrations (mg L^{-1})							
	HCO_3^-		Cl^-		$SO4^{--}$		$CO3^{--}$	
	GW	TSE	GW	TSE	GW	TSE	GW	TSE
Daryiah								
Summer	3.10	2.70	12.50	7.75	6.32	5.43	0.00	0.00
Autumn	3.35	2.60	12.35	7.95	5.30	4.75	0.00	0.00
Winter	4.85	3.70	11.85	6.85	7.40	6.59	0.00	0.00
Spring	3.40	2.80	12.65	7.40	7.32	6.41	0.00	0.00
Waseel								
Summer	5.30	3.30	7.15	5.05	7.33	6.21	0.00	0.00
Autumn	6.65	3.85	7.95	6.05	5.40	4.10	0.00	0.00
Winter	7.00	5.70	6.40	4.80	8.90	6.95	0.00	0.00
Spring	6.70	3.40	7.90	5.55	7.31	6.24	0.00	0.00
Ammaryah								
Summer	4.50	2.950	8.20	5.25	6.45	6.14	0.00	0.00
Autumn	5.10	2.90	9.20	6.05	6.05	5.12	0.00	0.00
Winter	6.40	4.80	6.55	4.90	6.80	6.60	0.00	0.00
Spring	5.90	2.80	7.75	6.25	6.24	5.32	0.00	0.00
LSD (0.05)								
Site (St)	1.59		1.49		1.84		0.0	
Season (Sn)	0.83		0.52		0.61		0.0	
Water (Wt)	0. 92		1.22		1.50		0.0	
St*Sn*Wt	4.48		4.20		5.20		0.0	

In view of the quality of irrigation water either groundwater or treated sewage effluent used throughout this investigation, it could be stated that sodium adsorption ratio (SAR) of groundwater and treated sewage effluent ranged from 1.93 to 2.95 me l^{-1} and 2.28 to 3.23 me l^{-1} respectively. SAR was calculated from the data of Na, Ca, and Mg recorded in Tables 2 &3. These values are in the usual range of irrigation water on the base of the guidelines for interpretation of water quality for irrigation of FAO according to Ayers and Westcot (1985) who reported that there is no restriction for surface and sprinkler irrigation water showing less than 3 me l^{-1} SAR. They also added that a slight to moderate restriction for surface irrigation showing 3 – 9 me l^{-1} SAR and > 3 me l^{-1} for sprinkler irrigation (severe restriction for SAR > 9 for both irrigation type).

Nitrogen, phosphorus and organic matter:

Data recorded in Table 4 clearly showed that ammonia concentrations were higher in TSE as compared to its content in ground water. Results also revealed that both sources of irrigation water in Daryiah region contained more ammonia than the other sites. Winter season showed high content of ammonia in each of TSE and groundwater. This is may be due to the suitable temperature at that season to most of the ammonifier organisms. Also it may be because the temperature at that season was not conducive for the transformation of ammonia to nitrate by nitrifiers bacteria. In general these results clearly indicate that the levels of ammonia in both sources of irrigation water are still in the usual range of irrigation water according to Shainberg and Oster (1978).

Table 4: Nitrogen and Phosphorus concentration (mg L^{-1}) of ground and sewage water as affected by site and season.

Seasons	Nitrogen and Phosphorus concentration (mg L^{-1})							
	NH_4^+		NO_3^-		Total Nitrogen		Total Phosphorus	
	GW	TSE	GW	TSE	GW	TSE	GW	TSE
Daryiah								
Summer	1.90	7.80	11.90	9.75	14.40	17.85	0.00	5.75
Autumn	2.70	10.50	10.10	8.10	12.90	18.80	0.00	4.35
Winter	4.90	14.65	9.40	5.40	14.40	20.25	0.00	5.63
Spring	2.40	6.15	6.10	3.15	8.70	9.70	0.00	4.20
Waseel								
Summer	1.55	2.40	10.55	8.90	12.60	11.95	0.00	5.85
Autumn	0.50	3.70	9.60	7.80	10.60	11.80	0.00	5.60
Winter	3.00	7.00	8.05	4.90	11.45	12.30	0.00	4.81
Spring	1.40	2.15	4.10	3.00	5.90	5.25	0.00	5.90
Ammaryah								
Summer	1.05	2.05	8.35	4.00	9.70	6.40	0.00	5.93
Autumn	0.35	0.65	6.45	3.65	6.95	4.70	0.00	5.80
Winter	2.45	3.00	5.75	4.35	8.40	7.45	0.00	5.92
Spring	0.70	2.05	3.85	2.40	4.95	4.75	0.00	6.10
LSD (0.05)								
Site (St)	1.60		1.55		2.75		0.93	
Season (Sn)	1.85		1.78		2.17		1.08	
Water (Wt)	1.31		1.26		1.24		-	
St*Sn*Wt	4.53		4.36		5.77		2.64	

The level of nitrates in each of ground water and treated sewage effluent were significantly varied (Table 4). The concentrations of nitrate were significantly higher in ground water compared to the treated sewage effluent. Irrespective to the source of water and seasons, the highest concentration of nitrate was generally observed in Daryiah, however Ammaryah region recorded the lowest concentrations for both sources of irrigation water. Nitrate concentration reached its maximum in summer because of the suitable temperature that stimulates the nitrifier's bacteria to oxidize ammonia to nitrate. The low concentrations of nitrate were recorded in spring season. In view of the World Health Organization standard (WHO, 1984) which put the limit of 45 mg L^{-1} nitrates as the highest tolerable nitrate content in drinking water, it could be easily recognized that the irrigation water under study were in the usual range to be used in agricultural purposes.

The occurrence of ammonium and nitrate in groundwater obtained from different wells of tested sites may result from a direct or indirect discharge of sewage effluent or associated with the application of nitrogen fertilizers. Total nitrogen content of irrigation water followed the same trend of ammonia and nitrate (Table 4). Ground water did not show any detectable amount of phosphorus; however TSE contained remarkable amount of phosphorus amounting to 6.1 mg L^{-1}. Both sources of irrigation water did not show any detectable amount of organic matter.

Heavy metals:

The influence of different sites, seasons and water source on heavy metals concentration in irrigation water is summarized in Table (5). Results clearly revealed that iron, manganese and zinc were found in low concentrations in both irrigation water sources, where no significant differences were recorded. Iron was the most dominant heavy metal in both sources of water either groundwater or TSE at the different sites and seasons. The highest amount of this element was recorded in summer season in the different sites. Undetectable amount of copper was noticed in both sources of waters where its value was below detection limit in all samples. The average of cadmium concentration was 0.01 mg l^{-1} for both sources of water, whereas chromium was only detected in one sample of groundwater being 1.03 mg l^{-1}. Both sources of water did not show any detectable amount of lead (below detection limit).

Table 5: Heavy metals concentration (ug L^{-1}) of ground and sewage water as affected by site and season.

Seasons	Heavy metals concentration (ug L^{-1})							
	Mn		Zn		Fe		Cu	
	GW	TSE	GW	TSE	GW	TSE	GW	TSE
Daryiah								
Summer	40	40	40	120	100	200	0.0	0.0
Autumn	0.0	20	40	80	100	160	0.0	0.0
Winter	10	20	60	20	100	120	0.0	0.0
Spring	10	10	20	10	100	100	0.0	0.0
Waseel								
Summer	40	30	20	100	100	190	0.0	0.0
Autumn	0.0	20	10	80	110	150	0.0	0.0
Winter	20	20	10	20	100	100	0.0	0.0
Spring	10	10	20	20	100	100	0.0	0.0
Ammaryah								
Summer	40	40	30	90	100	190	0.0	0.0
Autumn	0.0	10	20	70	100	140	0.0	0.0
Winter	20	10	10	10	100	100	0.0	0.0
Spring	10	10	20	10	100	100	0.0	0.0
LSD (0.05)								
Site (St)	19		36		152		0.0	
Season (Sn)	22		41		176		0.0	
Water (Wt)	16		29		124		0.0	
St*Sn*Wt	54		102		430		0.0	

The concentration of heavy metals recorded in TSE at different sites of Daryiah, Waseel and Ammaryah were below the levels recommended by Arizona state standards (Bouwer and Rice,1981), and WHO (1984). The lowest concentrations of heavy metals in treated sewage effluent may be referred to the removal of the most heavy metals with the sludge during the treatment methods. On the other hand, the source of sewage water of Riyadh region is only from domestic wastes (industrial wastewater not included). The secondary treatment also removes the heavy metals that escape from primary treatment, where the removal is usually accomplished by biological processes in which microbial cells accumulate or precipitate a high portion of heavy metals (Gadd, 1992 and Alig *et al.*, 1992). Results of the present work are in line with Al-Ogaily *et al.* (1999) who reported that the water quality parameters and heavy metals content in Wadi Hanifah, (Saudi Arabia) treated sewage stream water were within the permissible safe limits for agricultural purposes.

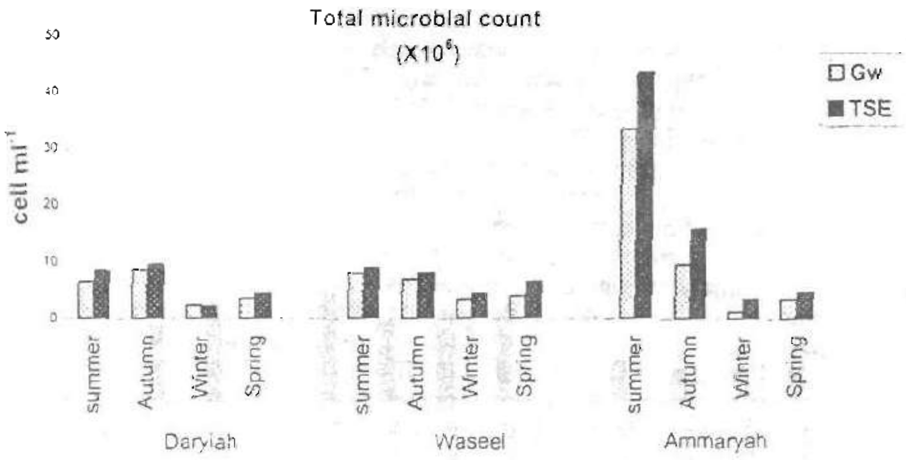
Microbial populations:

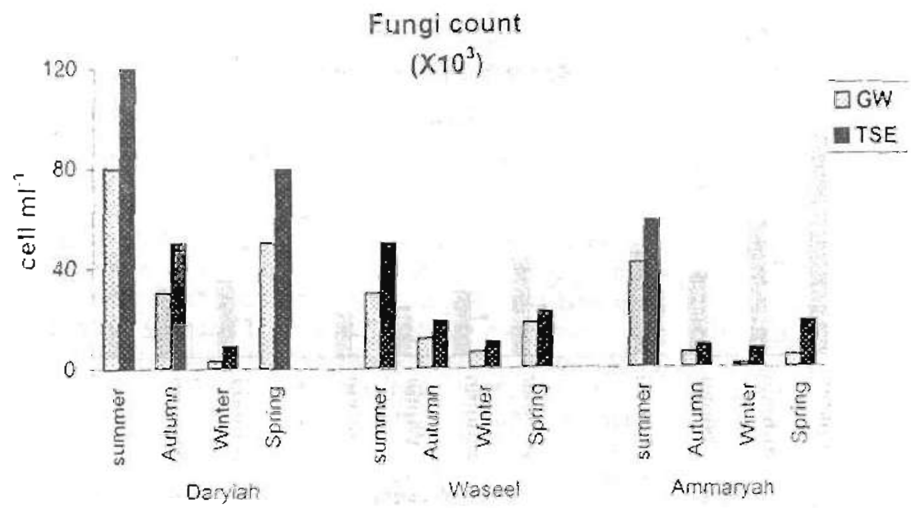
Total bacteria, fungi and streptomycetes populations showed different trends as affected by site, season and irrigation water sources (Fig 1 and 2). Microbial populations of Daryiah and Waseel sites did not show any significant differences, however, their counts were significantly higher in Ammaryah site. There were no significant differences between groundwater and TSE in their content of bacteria, although TSE contained higher numbers of microorganisms than groundwater has. Summer season generally, recorded the highest number of bacterial counts followed by autumn, spring and winter, respectively.

Fungal counts were significantly higher at Daryiah site as compared with the other sites. In contrast, the highest density of streptomycetes was recorded at Waseel site. Fungal and streptomycetes counts were significantly higher in TSE than groundwater. Regarding the effect of different seasons on the fungal and streptomycetes population it was found that they followed the same trend as total microbial counts since the summer season recorded the highest number and winter season was the lowest. Azotobacter counts (Fig. 2) followed the same trend as fungal counts.

The correlation between microbial populations of groundwater and TSE showed that a highly positive significant correlation existed in the case of streptomycetes count where $r = 0.9928$ ($P = 0.05$, $n = 12$). Fungal group gave a very low insignificant correlation ($r = 0.24$). In contrast, microbial counts showed a negative insignificant correlation coefficient (0.2195). In the case of soil microbial populations, both irrigation water sources gave the same trend but insignificant values were obtained for all microbial groups.

Biodiversity of microbial populations as affected by site, season and both sources of irrigation water is shown in Fig. (3&4). Results revealed that different microbial groups differed inconsistently between site, season and irrigation sources. The highest most probable numbers of different groups were found in TSE as compared to groundwater (1.3 to 22 fold higher than groundwater). Microbial communities appeared to be differed between sites where nitrifiers and sulfate reducers were found in high density at different sites than the other groups of microorganisms. Conversely, the density of

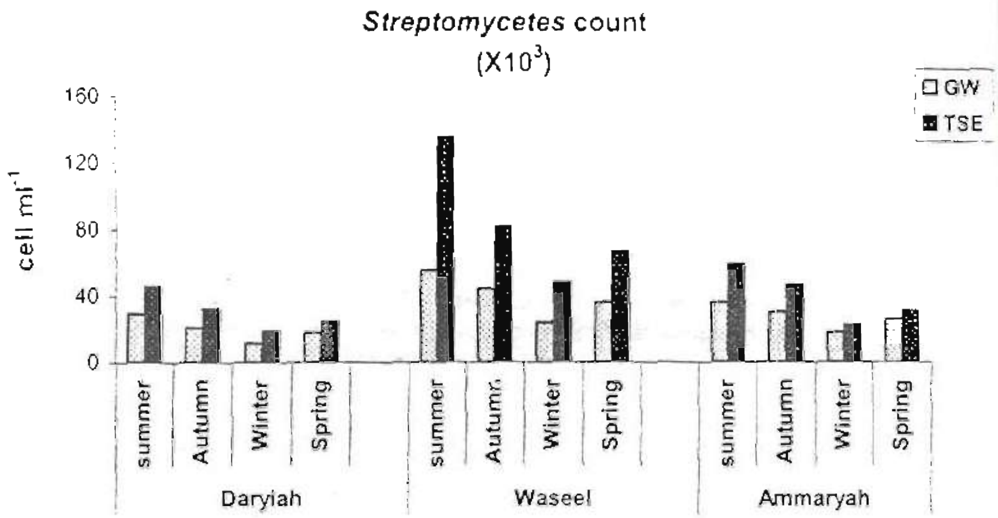


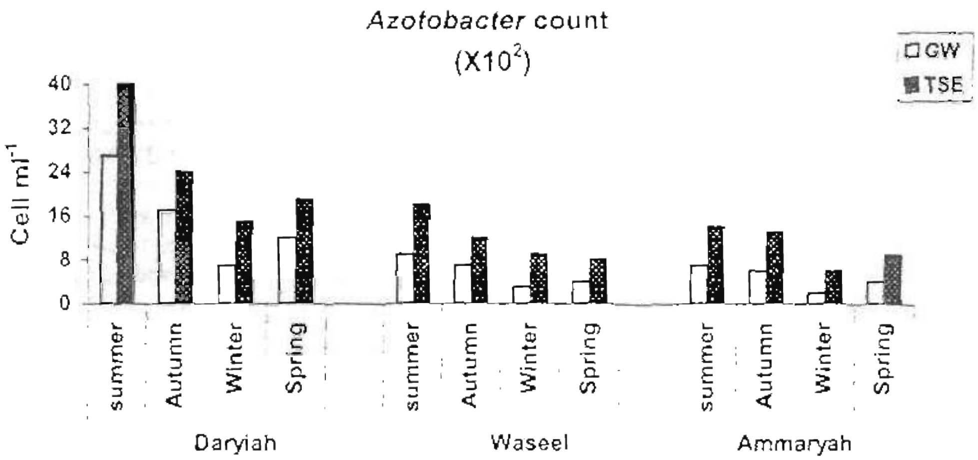


LSD (0.05)

	Total microbial count	Fungi
Site(St)	86.6	40.6
Season(Sn)	100.1	46.6
Water(Wt)	70.7	32.9
ST*Sn*Wt	244.9	114.1

Fig.1. Total and Fungi counts (cell ml^{-1}) of ground and sewage water as affected by site and season.





LSD (0.05)

	Actinomycetes	*Azotobacter*
Site(St)	31.1	2.27
Season(Sn)	36.2	2.62
Water(Wt)	25.6	1.85
ST*Sn*Wt	88.5	6.39

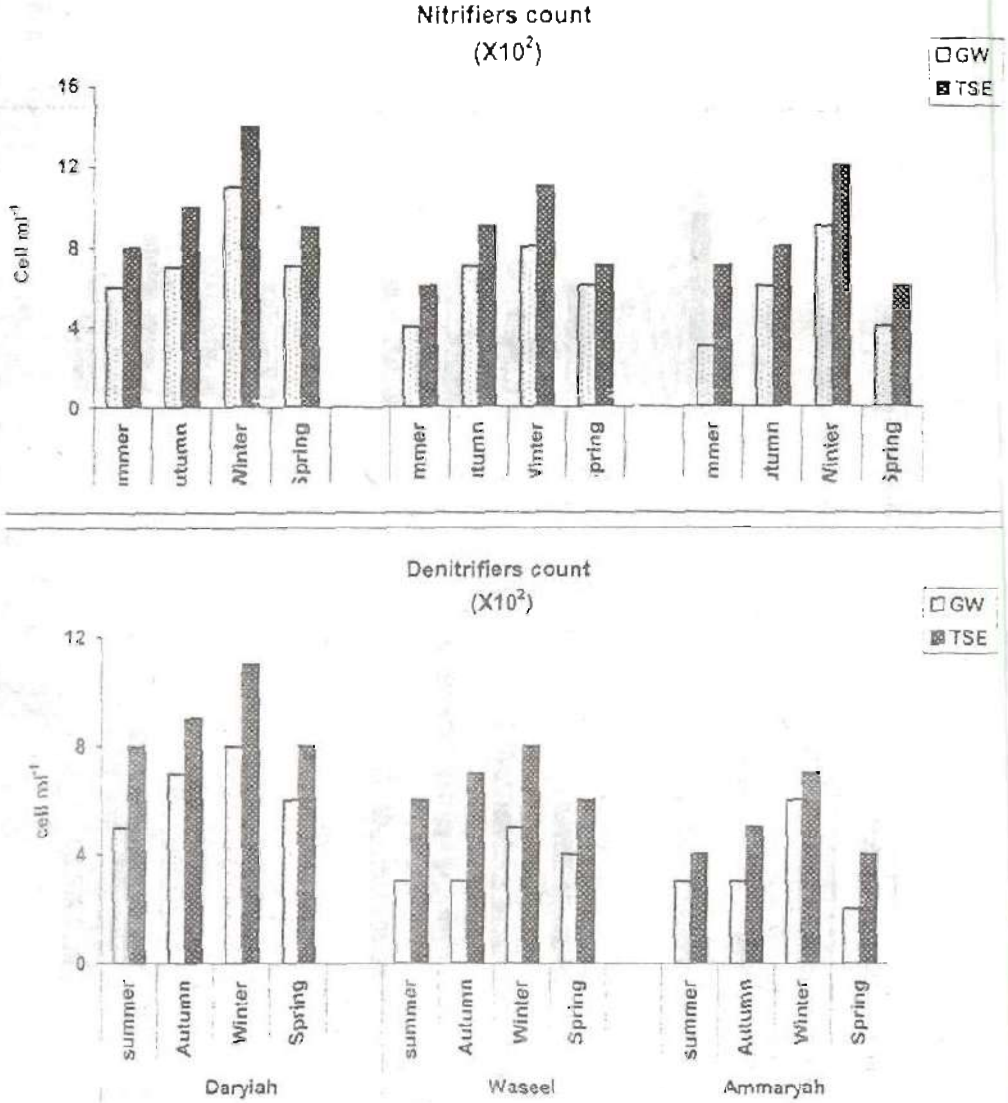
Fig.2. *Streptomycetes* and *Azotobacter* counts (cell ml^{-1}) as affected by season and site.

denitrifiers and N_2-fixers were significantly higher at Daryiah site than the other sites. Sulfate-reducers showed their highest density at Waseel site. During winter season irrigation water were richer in nitrifiers, denitrifiers, sulfate-reducers and S-oxidizers. This may be due to suitable temperature at that season for the growth of the mentioned groups. Nitrifiers group recorded the highest counts in winter season because of the high content of NH_4^+ which considered the substrate of the mentioned group.

Multiple-tube fermentation and Millipore filter technique for contamination of irrigation water with fecal and non-fecal coliform group indicated that all treated sewage effluent collected from different sites and seasons were contaminated with fecal coliform group. Groundwater collected from different sites exhibited the same trend except water samples collected from the wells in Daryiah site during summer season, Waseel site during the first three seasons (summer, autumn, and winter) and Ammaryah site during autumn season where neither fecal nor non-fecal coliform were detected. It means that the efficiency of secondary treatment is not quite enough to remove all microbial contamination. Abdel-Magid (1996) stated that high coliform count was evident in sewage effluent of Qassim region, Saudi Arabia in spite of achieving between 99.92 - 99.96 % removal efficiency which renders the effluent unacceptable for unrestricted irrigation.

In view of biochemical oxygen demand (BOD), it was found that the five-day BOD ranged from 3.69 to 4.32 mg l^{-1} for TSE and from 0.24 to 0.56 mg l^{-1} for groundwater at different sites. These low values of BOD were probably due to the absence of organic matter in both sources of irrigation water. The objective of secondary sewage treatment is to reduce BOD to an acceptable level. It may be added that the BOD_5 of TSE is relatively higher than groundwater. This may be due to the presence of higher amount of ammonia and higher density of nitrifying bacteria in TSE as compared to groundwater (Table 4 and Fig.3). It means that the consumed oxygen during five days of incubation referred mainly to the oxidation of ammonium by nitrifying bacteria. This result is in accordance with those observed by APHA (1967) who observed that the oxygen demand of sewage plant effluent, polluted water is exerted by carbonaceous organic materials, oxidizable nitrogen derived from ammonia or nitrite which serve as food for specific bacteria (*Nitrosomonas spp.* and *Nitrobacter* spp.) and certain chemical reducing compound (ferrous, sulfide and sulfite). Al-Ogaily (1999) also observed that the BOD of Wadi Hanifah stream (where secondary treatment effluent of Riyadh Domestic Sewage Treatment Plant is discharged) was 4.5 mg l^{-1}. Abdel-Magid (1996) demonstrated that the BOD_5 of sewage effluent of Unaizah city, Saudi Arabia ranged from 13.5 to 19 mg l^{-1}. These values were higher than that observed in the present study. This is probably due to the high efficiency of Riyadh Domestic Sewage Treatment Plant to remove and eliminate the organic matter during the secondary treatment.

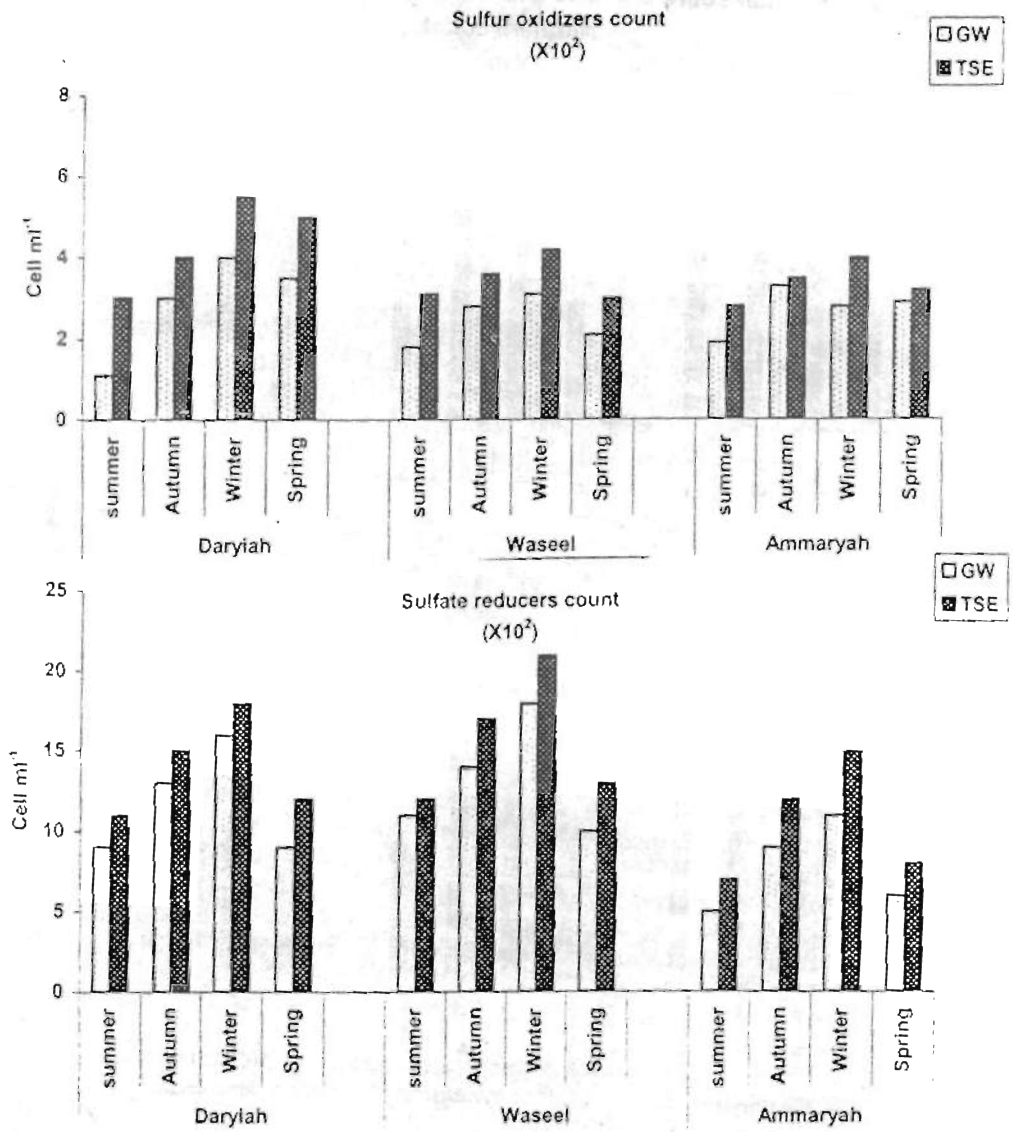
From the aforementioned results it could be concluded that treated sewage effluent is of enough quality for agricultural purposes as groundwater. Due to the presence of fecal coliform in this effluent which is used as indicators of sewage pollution, it can be safely used for irrigation the wood trees, forests and landscape.



LSD (0.05)

	Nitrifiers	Denitrifiers
Site(St)	1.16	1.21
Season(Sn)	1.34	1.4
Water(Wt)	0.95	0.99
ST*Sn*Wt	3.28	3.41

Fig.3. Nitrifiers and denitrifiers counts of ground and sewage water as affected by site and season.



LSD (0.05)

	Sulfur oxidizers	Sulfate reducers
Site(St)	0.24	1.24
Season(Sn)	0.28	1.43
Water(Wt)	0.19	1.01
ST*Sn*Wt	0.68	3.49

Fig.4. Sulfur oxidizing and sulfate reducing bacterial counts of ground and sewage water as affected by site and season.

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تقويم صلاحية المياه الجوفية ومياه الصرف الصحى المعالجة للرى بالمملكة العربية السعودية

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تمت دراسة مقارنة لتقييم جودة كل من المياه الجوفية ومياه الصرف الصحى المعالجة ثانويا بمنطقة الرياض وذلك لإستخدامها فى الأغراض الزراعية حيث تم جمع عينات من مصدرى المياه تحت الدراسة من ثلاث مواقع مختلفة هى الدرعية – الوصيل – العمارية خلال فصول السنة الأربعة. وقد أوضحت النتائج زيادة درجة ملوحة المياه الجوفية زيادة معنوية عن مياه الصرف الصحى المعالجة كما كان محتواها من كاتيونات الكالسيوم والماغنسيوم والصوديوم وأنيونات الكلوريد والبيكربونات أعلى من مثيلاتها بمياه الصرف الصحى المعالجة. ولقد وجد أن كلا النوعين من المياه أحتوى على تركيزات قليلة من النتروجين النشادرى أو النتراتى وكذلك المعادن الثقيلة مثل الحديد والمنجنيز والزنك والنحاس حيث كانت تركيزاتها أقل من الحد المسموح به فى مياه الرى. وأظهرت الدراسة أنه لا يوجد فرق معنوى بين العدد الكلى للميكروبات فى موقعى الدرعية والوصيل وعلى العكس كانت هناك زيادة معنوية فى الأعداد الكلية للميكروبات بموقع العمارية. كما لم توضح النتائج أى فروق معنوية لأعداد الميكروبات الكلية فى نوعى المياه تحت الدراسة ومع ذلك فإن الأعداد كانت دائما أعلى فى مياه الصرف الصحى المعالجة عنها فى المياه الجوفية . وقد وجد زيادة معنوية فى أعداد الفطريات فى موقع الدرعية مقارنة بالموقعين الأخرين تحت الدراسة وعلى العكس سجلت أعداد الأكتينوميسات أعلى قيمة فى موقع الوصيل. وبصفة عامة وجد أن هناك زيادة معنوية لأعداد الفطريات والأكتينوميسات فى المياه الجوفية مقارنة بمياه الصرف الصحى المعالجة. ولقد أوضحت النتائج أيضا أن المجاميع الميكروبية الأخرى مثل ميكروبات النترتة وعكس النترتة والمؤكسدة والمختزلة للكبريت تتأثر أعدادها تبعا لموقع ونوعية المياه وفصول السنة المختلفة فقد وجد أن أعداد هذه الميكروبات أعلى فى مياه الصرف الصحى بما يعادل ١,٣ إلى ٢٢ ضعف مقارنة بما هو موجود فى المياه الجوفية. ومن ناحية تأثير الموقع وجد أن أعداد ميكروبات النترتة وإختزال الكبريت سجلت أعلى القيم فى المواقع المختلفة مقارنة بأعداد ميكروبات عكس النترتة والميكروبات المؤكسدة للكبريت كما وجد أن موقع الدرعية سجل أعلى زيادة معنوية فى أعداد ميكروبات تثبيت النتروجين الجوى مثل الأزوتوباكتر ومن جهة أخرى فقد سجلت ميكروبات إختزال الكبريت أعلى زيادة معنوية فى موقع الوصيل وبناءاً على النتائج المتحصل عليها نجد أن أن مياه الصرف الصحى المعالجة بمنطقة الرياض تصلح للرى جنبا الى جنب مع المياه الجوفية ونظرا لوجدود بعض التلوث ببكتريا القولون بهذه النوعية من المياه فينصح باستخدامها لرى الأشجار الخشبية والغابات والمسطحات الخضراء ومحاصيل العلف حتى يكون إستخدامها أمن صحيا.