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Properties of Arid Soils Irrigated with Treated Sewage Effluent Groundwater in Riyadh Region, Saudi Arabia

F.N. Barakah[1], R. A. Abdel Aziz[2], E. M. Ramadan[1] and A. M. Heggo[1]

1-Department of Soil Science, College of Agriculture, King Saud University, P.O. Box ,2460 Riyadh 11451, Saudi Arabia

2-Agricultural Microbiology Department Research Center, Cairo, Egypt.

A STUDY was conducted to find out the effect of 20 years irrigation with groundwater and treated sewage water (TSE) on some properties of calcareous soil . The study was carried out at three different sites irrigated with both water types and followed during four seasons. Results revealed that EC of groundwater (2.25dS m^{-1}) was significantly higher than TSE and consequently led to increase soil salinity among different sites and seasons. Soil irrigated with groundwater contained significantly higher quantities of Ca^{2+}, Mg^{2+}, Na^{+} and K^{+} cations and sulfate anion than soils irrigated with TSE. Both irrigation waters had a very low amount of NH_4-N, NO_3- N, Fe, Mn, Zn, and Cu, which below the levels recommended for water quality. The present study demonstrates that after twenty years of using groundwater for irrigation of soils at Riyadh region, a major impact on soil salinity took place showing an inhibitory effect on soil microbial populations. Contradictory to that, treated sewage effluent did not show any deleterious effects on soil properties but led to increase many of useful biological processes specially which play an important role in soil fertility such as nitrogen fixation and nitrification. The minor effect on denitrifiers and sulfate-reducers may be attributed to the texture of soil in this region where anaerobic conditions is not prevalence. Results indicated that treated sewage effluent could be used for agricultural purposes as groundwater. The present study suggests to reuse treated sewage effluent in a large scale in Saudi Arabia for irrigation of *woody trees or foresty.*

Keywords Treated sewage effluent, Groundwater, Irrigation, Microbial populations, Soil properties.

Saudi Arabia lies in one of the most fragile agroecological zones of the world. Scarcity of rainfall and the extremely high temperatures over several months contribute to its aridity. In Saudi Arabia, as in many other parts of the world, soil moisture from rain and from groundwater is insufficient for the requirements of plant life. The water deficiency must be compensated by irrigation. As good quality irrigation water becomes more and more limited, irrigated agriculture in Saudi Arabia makes increasingly use of treated sewage water.

During the last two decades an attention has been focused by Ministry of Agriculture and Irrigation, Saudi Arabia on the municipal sewage effluent for industrial and agricultural purposes, especially outside big cities such as Riyadh, Jeddah, Madena, Qassim and East province. Baddesha *et al.* (1997) indicated that irrigation with sewage water for 18 month to eucalyptus field (Fucalyptus hybrid, *E.tereticornis*) significantly decreased pH and electrolyte conductivity in the surface soil layer, but it significantly increased organic carbon, available nitrogen, phosphorus, potassium, micronutrients, Ca and Mg. Soluble Na content decreased in the soils surface layer. Uptake of Zn, Mn, Fe and Cu by alfalfa plants was increased with increasing the frequency of irrigation with sewage water (Barakah, 1995). The salt deposited in soil per season was 160 and 83 t ha^{-1} for wheat and alfalfa respectively, as a result of irrigation with groundwater in Qassim region, Saudi Arabia (Abdel-Aal *et al.*, 1997).

Microorganisms are also affected by irrigation water quality. Nitrification by nitrifying bacteria occurred in soil cores receiving surface applications of anaerobically digested sewage sludge (Burton *et al.* (1990) . Irrigation with secondary-treated municipal wastewater of Riyadh region, Saudi Arabia decreased arbuscular mycorrhizal root infection of plants (Al-Rajhi, 1992). Monitoring of heterotrophic N-fixing bacteria and presumptive coliforms in two Libyan sewage treatment plants showed that tertiary treatment of effluent by chlorination killed these bacteria (Betaieb and Jones, 1992). However, the irrigation reservoirs that received the treated sewage water, contained large numbers of both types of bacteria. As the proportion of N-fixers to presumptive coliforms was much less in sewage water than in the irrigation reservoirs, it is probable that the irrigation water became contaminated by a source other than sewage (Betaieb and Jones, 1992).

In a four year study with annual sludge applications to a cotton crop on a clay loam soil, Brendecke *et al.* (1993) found no significant adverse effects on soil microbial populations or activity for soil bacteria, actinomycetes and fungi. Values of nodulation, nitrogenase activity and alfalfa plant dry weight were higher in soil irrigated with mixture of sewage water: tap water at ratio of 4:1 (Barakah, 1995).

The present work studied the effect of irrigation with groundwater and treated sewage effluent of Riyadh region on physicochemical properties and microbial populations of calcareous soils at three different sites during four seasons.

Material and Methods

In the current work three representative sites were chosen from Riyadh region at about 40-km northeast down town (56.2°N, 33.8°E). The three sites were Daryiah, Waseel, and Ammaryah farmlands which were irrigated with groundwater pumped from deep wells or municipal secondary-treated sewage effluent from Riyadh pumping station (Riyadh Domestic Sewage Treatment Plant) for 20 years.

Sampling

Soil samples (three replicates) from the different sites were collected during four seasons, e.g., October 1998, April 1999, August 1999 and February 2000 with respective temperature range of 15.3 - -34.8, 17.1 -33.3, 23.3 - 42.2 and 8.5-24.4°C, respectively. The corresponding rainfall figures were 2.5,16,0 and 8.5 mm. The area of each site was previously divided in two parts one of them was irrigated with groundwater and other spot was irrigated with municipal secondary-treated sewage effluent (TSE). Representative irrigation water samples from Riyadh region (groundwater and TSE) were collected from distribution tanks in sterilized bottles (500 ml capacity). Characteristics of the two irrigation water sources are shown in Table 1. Iron, manganese and zinc were found in very low concentrations in both irrigation type (Table, 1). Undetectable amount of copper and lead were noticed in both irrigation waters, where its values were below detection limit in all samples (Table 1). The average of cadmium was 0.01μg l^{-1} for both irrigation water types, whereas chromium was only detected in groundwater being 1.03μg l^{-1}.

Soil samples (about 2 Kg) were also randomly taken at 5-30 cm depth from each site in plastic bags. The samples were transferred directly to the laboratory for physical, chemical and microbial analyses.

TABLE 1. Analyses of groundwater and treated sewage effluent of Riyadh region.

Characters	Groundwater	Treated sewage effluent	Characters	Groundwater	Treated sewage effluent
PH	7.71 a	7.54 a	NH_4-N (mg L^{-1})	2.63 b	4.89 a
EC (dS m^{-1})	2.25 a	1.49 b	NO_3-N (mg L^{-1})	10.0 a	8.7 a
Ca^{+2} (meq L^{-1})	7.07 a	4.63 b	Total-N (mg L^{-1})	13.4 a	14.8a
Mg^{+2} (meq L^{-1})	8.28 a	3.81 b	Total phosphorus (mg L^{-1})	0.001 b	5.5 a
Na^{+}(meq L^{-1})	6.30 a	5.64 b	Organic matter (%)	Nil	0.03
K^{+}(meq L^{-1})	0.14 b	0.36 a	Fe (µg L^{-1})	62 a	65 a
Cl^{-}(meq L^{-1})	9.21 a	5.35 b	Zn (µg L^{-1})	10 a	12 a
HCO_3^{-} (meq L^{-1})	5.03 a	3.27 b	Mn (µg L^{-1})	17 a	16 a
$SO_4^{=}$(meq L^{-1})	6.07 a	5.81 a	Coliform group (cells / ml)	+ (7)	+++ (18)

Means followed by the same letter in each row are insignificantly different according to LSD test ($p = 0.05$) .

Physical and Chemical Analyses

Soil texture (sand. silt and clay percentage, using hydrometer method), moisture content field capacity and saturation percentage (Black, 1965, Richards, 1954) of different soil samples were determined among different seasons. The soil texture analyses revealed that the texture grade of Daryiah, Waseel, and Ammaryah soils either irrigated with groundwater or treated sewage effluent (TSE) were sandy loam, sandy clay loam and sandy clay loam, respectively. Soil and water samples of different sites were also analyzed for electrical conductivity, pH, soluble cations & anions, NH_4^+ and NO_3^- (Rhoades, 1982). Organic matter (Mebius, 1960), total N (Bremner and Mulvancey, 1982), total P (Olsen and Dean, 1982), total $CaCO_3$) calcimeter procedure, Black, 1965) and heavy metals (Fe, Mn, Zn and Cu) using Perkin Elmer Model 2380 Atomic Absorption Spectrophotometer (AAS) were determined. 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.

Microbiological Determinations

Different microbial populations were determined directly in soil samples. Plate count technique was followed for 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 non-symbiotic N fixers (Abdel-Malek and Ishac, 1968), nitrifying bacteria (Bodelier *et al.*, 1998), denitrifiers (Abdel-Malek *et al.*, 1974), sulfate-reducers (Meynell and Meynell, 1970) and sulfur- oxidizers (Brock ,1979), were counted using dilution frequency method (Most Probable Number, MPN). Multiple-tube fermentation and Millipore techniques (WHO, 1984) were used to detect the coliforms in irrigation water and soils. Biochemical oxygen demand (BOD) was determined in groundwater and TSE using a dissolved oxygen meter (Model 9300, Jenway Limited, England). Dissolved oxygen was estimated initially and after 5 days of incubation at 20 °C (APHA, 1967), and BOD_5 was calculated.

To study the effect of one factor from the three different factors under study (sites, seasons and irrigation water type), we took into consideration this factor and neglected the others. This is clearly showed from the results presented in the different tables.

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 (5 % probability level). The correlation coefficient (r) was also estimated.

Results and Discussion

Electrical conductivity and pH values

Soils irrigated with groundwater showed significantly higher values of EC (soil paste) than soils irrigated with TSE (Table 2). With respect to the effect of sites on electrical conductivity of soil, it was found that the EC of Waseel site was significantly higher than other two sites. Among seasons EC values were highest in spring (Apr.1999) and summer (Aug. 2000) being 2.34 and 2.33 dS m^{-1} respectively, while fall season (Oct.1998) showed the lowest values (1.83 dS m^{-1}).

TABLE 2. Electrical conductivity and pH values of soils as affected by sites, seasons and type of irrigation water.

Source of variability	EC_e (dS m^{-1})	pH
	Sites	
Daryiah	1.73 ^{b}	7.6 ^{b}
Waseel	2.90 ^{a}	7.5 ^{b}
Ammaryah	1.81 ^{b}	7.7 ^{a}
	Seasons	
Oct.1998	1.83 c	7.9 ^{a}
Apr.1999	2.34 ^{a}	7.6 ^{a}
Aug.1999	2.33 ^{a}	7.6 ^{a}
Feb. 2000	2.08 ^{b}	7.6 ^{a}
	Irrigation type	
Groundwater	2.48 ^{a}	7.7 ^{a}
Treated effluent	1.81 ^{b}	7.6 ^{b}

Means followed by the same letter in each column are insignificantly different according to LSD test ($p = 0.05$).

Generally, it could be stated that the salinity of groundwater was higher than TSE Table 1 and consequently led to increase the salinity of soil irrigated with groundwater as compared to TSE. The positive linear correlation between EC of groundwater and EC of soil ($r = 0.2468$, $n = 12$) and the negative correlation between EC of effluent and EC of soil ($r = - 0.2705$, $n = 12$) confirmed this finding. Because of the sewage water is mostly of desalinated origin and does not contain discharges from industrial wastewater or other wastes, its EC are low. This result is in line with those observed by Abdel-Magid (1996) who observed that EC and pH values of sewage effluent of Qassim region, Saudi Arabia were within the acceptable limits. On the other hand, Radwan *et al.* (1995) observed that the repeated fertilization with treated sewage effluent led to increase soil acidity and inhibited alkane biodegradation in oil Kuwaiti soils. Tarchitzky *et al.* (1999) observed that the most of salt added during domestic and industrial usage remain in the irrigation water and may eventually reach the soil.

Soluble cations and anions

The highest values of Mg^{2+}, Na^{+} and K^{+} were recorded in soils of Waseel and Ammaryah sites (Table 3). The recorded values were significantly higher than Daryiah site. The highest quantity of Ca^{2+} cation was at soils of Ammaryah site being 12.25 ml^{-1} (significantly higher than other sites). Irrespective to different sites and water irrigation types results revealed that the highest amount of Ca^{2+}, Na^{+} and K^{+} were observed at spring season (Apr.1999) whereas Mg^{2+} showed its peak at summer season (Aug.1999). In contrast, high significant values of soluble cations were found in soil irrigated with groundwater, which was approximately 2 fold higher than soluble cations of soil irrigated with TSE. Due to the increase of soluble cations in soils irrigated with groundwater, correlation coefficient was estimated for each cation in groundwater and soil. There was a linear positive correlation of 0.2954, 0.5860* and 0.6126* (*significant at 0.05, n= 18) for Ca^{2+}, Mg^{2+} and Na^{+} respectively.

TABLE 3. Soluble cations and anions of soil as affected by sites, seasons and irrigation water type.

Source of Variability	Cations (meq l^{-1})				Anions (meq l^{-1})		
	Ca^{2+}	Mg^{2+}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	SO_4^{2-}
Sites							
Daryiah	6.41 b	6.22 b	5.59 b	0.356 b	7.99 b	5.38 a	6.06 b
Waseel	8.49 b	10.26 a	9.36 a	1.023 a	12.09 a	6.10 a	11.80 a
Ammaryah	12.25 a	9.67 a	11.19 a	1.112 a	10.78 a	6.99 a	14.60 a
Seasons							
Oct.1998	7.75 bc	4.77 b	4.41 b	0.445 b	10.56 a	4.86 c	12.35 a
Apr.1999	11.20 a	10.08 a	13.53 a	1.538 a	12.02 a	6.72 a	10.20 a
Aug.1999	10.61 ab	10.73 a	10.56 a	0.770 b	11.49 a	5.43 bc	11.67 a
Feb.2000	6.65 c	9.29 a	6.37 b	0.568 b	7.08 b	6.29 ab	9.06 a
Irrigation water							
Groundwater	12.06 a	11.87 a	11.65 a	1.090 a	12.97 a	6.15 a	13.82 a
Treated effluent	6.04 b	5.56 b	5.79 b	0.571 b	7.61 b	5.50 a	7.82 b

Means followed by the same letter in each column are significantly different according LSD test (p = 0.05)

Sulfate and chloride were the most dominant anions in soils of Ammaryah and Waseel sites Table 3, being significantly higher than Daryiah site. In contrast, HCO_3 did not show any significant differences among different sites. Sulfate did not show significant differences between seasons (ranged from 9.06 to 12.35 meq l^{-1}) .Chloride also exhibited the same trend except winter season

(Feb. 2000), where its value significantly was lower than other seasons being 7.08 meq l^{-1}. Soils irrigated with groundwater contained significantly higher amount of sulfate and chloride than that irrigated with TSE representing the most dominant anions. Correlation between anions in irrigation water and soil showed that there is a significant positive correlation (r = 0.5113) in the case of HCO_3 and non-significant positive correlation (r = 0.2059) for chloride (p = 0.05, n = 18), in contrast sulfate gave insignificant negative correlation (r = -0.05)

Nitrogen, phosphorus and organic matter

There was no obvious variation of ammonium soil content as affected by site and seasons, while soils inrigated with groundwater contained significantly higher quantity (12.3 mgl^{-1} than soils irrigated with TSE (Table 4). Ammaryah

TABLE 4. Ammonium, nitrate, total nitrogen (TN), total phosphorus (TP), heavy metals and organic matter (OM) of soil as affected by sites, seasons and irrigation water type.

Source of variability	(mg Kg^{-1} soil)								
	NH_4-N	NO_3-N	Total-N	Total-P	Fe	Zn	Mn	Cu	Organic matter (%)
Sites									
Daryiah	10.7 ^{a}	6.4 ^{b}	511 ^{a}	527 ^{ab}	3690 ^{b}	39.5 ^{a}	79 ^{b}	19.9 ^{a}	0.78 ^{b}
Waseel	12.2 ^{a}	6.3 ^{b}	535 ^{a}	565 ^{a}	6990 ^{a}	37.1 ^{a}	148 ^{a}	17.1 ^{b}	0.99 ^{a}
Ammaryah	11.2 ^{a}	14.8 ^{a}	571 ^{a}	492 ^{b}	7070 ^{a}	35.5 ^{a}	153 ^{a}	17.8 ^{a}	1.02 ^{a}
Seasons									
Oct.1998	9.8 ^{a}	9.6 ^{ab}	539 ^{ab}	516 ^{ab}	5912 ^{b}	29.5 ^{b}	157 ^{a}	22.3 ^{b}	1.00 ^{ab}
Apr.1999	11.6 ^{a}	5.8 c	578 ^{a}	510 ^{b}	8028 ^{a}	46.5 ^{a}	135 b	11.7 ^{c}	0.81 c
Aug.1999	12.5 ^{a}	12.8 ^{a}	537 ^{ab}	586 ^{a}	5444 ^{b}	51.3 ^{a}	151 ^{a}	25.7 ^{a}	1.03 ^{a}
Feb.2000	11.5 ^{a}	8.4 ^{bc}	495 ^{b}	500 ^{b}	4282 ^{c}	22.2 ^{b}	76 ^{c}	13.5 ^{c}	0.89 ^{bc}
Irrigation type									
Ground Water	12.3 ^{a}	11.3 ^{a}	537 ^{a}	474 ^{b}	6551 ^{a}	42.9 ^{a}	148 ^{a}	20.0 ^{a}	0.71 ^{b}
TSE	10.3 ^{b}	7.0 ^{b}	542 ^{a}	581 ^{a}	5283 ^{b}	31.8 ^{b}	112 ^{b}	16.6 ^{b}	1.15 ^{a}

Means followed by the same letter in each column are insignificantly different according to LSD test (p=0.05).

site, summer season and soil irrigated with groundwater showed the highest significant values of soil nitrate being 14.8,12.8 and 11.3 mgl^{-1} respectively. A considerable amount of total N and total -P was observed in soils of different sites as affected by seasons and irrigation water type but they did not registered a remarkable variations. Overall the amount of TP in soil irrigated with TSE was significantly higher than that irrigated with groundwater. Organic matter was significantly increased in soils irrigated with TSE comparing to soils irrigated with groundwater (Table 4).

Heavy metals

Iron was the predominant trace element in soils where considerable amount were recorded among different sites and seasons (Table 3). The highest significant quantities were found in soils collected at spring season. Ammaryah & Waseel soils recorded the highest Fe content as compared to Daryiah site. Zinc did not show any significant variations in different sites, whereas the maximum concentrations were registered at spring and summer seasons. Irrespective to sites and seasons, heavy metals concentrations except Zn in soil irrigated with groundwater were significantly higher than soils irrigated with TSE. Their concentrations in soils irrespective to different sites, seasons and irrigation water type were in order Fe > Mn > Zn > Cu. Concentrations of heavy metals recorded in TSE (Table 1) 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 water may be referred to the removal of the most heavy metals with the sludge during treatment methods. On the other hand, the source of sewage water of Riyadh region is only from domestic wastes. 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). The irrigation of soil with this effluent did not lead to increase heavy metal concentrations as compared to groundwater at different sites. This finding is in line with Al-Ogaily *et al.* (1999) who reported that the water quality parameters and heavy metals contents in Wadi Hanifah, Saudi Arabia treated sewage stream water were within the permissible safe limits for agricultural purposes. Contradictory to this result, Gadallab (1994) and Szewezuk and Sugier (1996) observed that the irrigation with sewage led to enrich the heavy metals content of soil. This variation may be referring to the original source of sewage water and the stages of treatments.

Microbial populations

Bacterial populations of all sites did not show any significant differences in soils (Table 5) Fungal counts were significantly higher at Daryiah site than other sites. In contrast, the highest density of streptomycetes was recorded at Waseel site. Concerning the effect of different seasons, it was found that the highest density of soil microbial population was recorded in summer, winter and spring seasons for bacteria, fungi and streptomycetes, respectively. Irrigation water type was differed in its effect since, soils irrigated with groundwater gave significantly higher counts of bacteria and lower density of streptomycetes than soil irrigated with TSE (Table 5).

TABLE 5. Total bacterial, fungi and streptomycetes counts of soils as affected by sites, seasons and irrigation water type.

Source of variability	Total bacteria ($\times 10^6$)	Fungi ($\times 10^4$)	Streptomycetes ($\times 10^4$)
Sites			
Daryiah	43	92	49
Waseel	59	59	97
Ammaryah	51	48	63
Seasons			
Oct.1998	65	49	45
Apr. 1999	26	65	101
Aug. 1999	82	42	82
Feb. 2000	20	112	73
Irrigation water types			
Ground water	79	67	51
TSE	27	69	84

LSD for (P= 0.05)

Source of variability	Bacteria	Fungi	Streptomycetes
Sites	22.98	31.21	30.35
Seasons	16.53	36.15	23.97
Irrigation water types	18.76	25.52	22.72

Biodiversity of microbial populations evaluated by most probable number (MPN) as affected by sites, seasons and irrigation type is shown in Table 6. Results revealed that different microbial groups differed inconsistently between sites, seasons and irrigation type. Counts of nitrifiers showed no significant differences among the studied sites. However, soils of Waseel site recorded the highest numbers of denitrifiers bacteria as compared to the other sites. Soils of Daryiah site showed the highest counts of aerobic N-fixers and sulfate reducing organisms, while sulfur oxidizing bacteria was found in high density at Waseel site. In general the low counts of denitrifiers and sulfate reducing organisms in the different sites may be attributed to the sandy soil texture in this region where the anaerobic conditions is not prevalence. Summer season showed the highest densities of the studied organisms as compared to the other seasons. Regarding to effect of the irrigation water type it was found that the highest counts of the different studied organisms were recorded in soils irrigated with TSE as compared to that irrigated with groundwater.

Multiple-tube fermentation and Millipore filter technique for contamination with fecal and non-fecal coliforms group indicated that both sources of irrigation water and soils at different sites were contaminated with fecal coliforms group. This means that the efficiency of secondary treatment is not quite enough to remove all coliforms. Abdel-Magid (1996) stated that high coliform count was evident in sewage effluent of Qassim region, Saudi Arabia, in spite of achieving 99.92-99.96.% between removal efficiency which renders the effluent unacceptable for unrestricted irrigation.

Generally, it could be concluded that the microbial community of different groups were highly affected by sites, seasons and irrigation type. Bacterial density was the most dominant organisms followed by fungi and streptomycetes. The highest fungal count found at Daryiah site may be due to the low moisture content and saturation percentage (sandy loam) of soil in this site (7.7 and 27.3 % respectively) as compared to the other sites This group also showed the same trend at winter season where temperature (24.4 °C) was more suitable for propagation of many fungi than other seasons. Waseel soil showed higher population of streptomycetes than other sites. Soil irrigated with TSE contained higher densities of sulfate-reducers as compared to the groundwater irrigated soils. This may be attributed to the occurrence of high concentration of sulfate in such sites, which led to increase the proliferation of sulfate-reducing bacteria than other groups. Peters (1995) reported that sulfate-reducing bacteria could be enriched in desert soil tested.

TABLE 6. Counts of Nitrifiers, Denitrifiers, Aerobic nitrogen fixers, Sulfate - reducers and Sulfur-oxidizing bacteria as affected by sites, seasons and irrigation water type

Source of variability	Nitrifiers ($\times 10^3$)	Denitrifiers ($\times 10^2$)	Aerobic N-fixers	Sulfate reducers	Sulfur oxidizers
Sites					
Daryiah	46	53	430	120	826
Waseel	54	77	130	11	1060
Ammaryah	49	12	250	5	30
Seasons					
Oct. 1998	54	12	160	40	30
Apr. 1999	13	1	140	30	70
Aug. 1999	131	65	680	100	430
Feb. 2000	10	48	100	20	30
Irrigation water types					
Groundwater	43	28	76	4	111
TSE	57	66	462	88	1180
LSD for (P=0.5)					
Sites	12.3	27.9	154.6	42.5	276.8
Seasons	36.8	34.7	258.4	23.8	126.3
Irrigation water Type	9.2	24.5	249.3	57.5	624.7

All microorganisms enumerated by most probable number technique showed higher densities in soils irrigated with TSE than soils irrigated with groundwater. This may be due to the organic matter content of TSE, which activate the growth of these microbial groups. Autumn season showed higher densities of N-fixers, denitrifiers and S-oxidizers where temperature reaches 34.8°C as compared to other seasons. It means that the temperature of the other seasons suppressed the proliferation of these groups. Milic *et al.* (1998) reported that the numbers of microorganisms of all types (aerobic heterotrophy, ammonifiers and free N_2-fixers, but not nitrifiers) was large, in most cases more so in August than in April in chernozem soil, Yugoslavia.

The present study demonstrates that after 20 years of using groundwater for irrigation of soils at Riyadh region, a major impact on soil salinity took place showing an inhibitory effect on soil populations. Contradictory to that treated sewage effluent did not show any deleterious effects on soil properties but led to increase many of useful biological processes especially which play an important role in soil fertility such as nitrogen fixation and nitrification. The minor effect on denitrifiers and sulfate-reducers may be attributed to the texture of soil in this region where anaerobic conditions are not prevalent. Treated sewage effluent is of equal quality as groundwater for agricultural purposes. So the use of treated sewage effluent was feasible and is also recommended. The present work suggests the reuse treated sewage effluent in a large scale in Saudi Arabia for irrigation of woody trees, landscape and forestry in the eastern part of Saudi Arabia.

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خواص الترب الجافة المروية بمياه المجاري المعالجة والمياه الجوفية فى منطقة الرياض ا لمملكة العربية السعودية

د. فهد ناصر البركة [١] -د. رضا عبد الظاهر عبد العزيز [٢] -د. الشحات محمد رمضان [١] -د. على محمد حجو [١]

١-قسم علوم التربة - كلية الزراعة - جامعة الملك سعود. ص.ب. ٢٤٦٠ الرياض ١١٤٥١ - المملكة العربية السعودية .
٢- قسم الميكروبيولوجيا الزراعية - المركز القومى للبحوث - القاهرة - مصر.

أجريت دراسة مقارنة لمعرفة تأثير الرى لمدة عشرون عاما بالمياه الجوفية ومياه الصرف الصحى المعالجة على بعض خواص الترب الجيرية الجافة بمنطقة الرياض واشتملت الدراسة علي ثلاث مواقع مختلفة تروى بهاتين النوعيتين من المياه وذلك لمدة أربعة مواسم متتالية. وقد أوضحت النتائج أن درجة التوصيل الكهربى (٢٥ . ٢ ديسى سيمن/م)كانت أعلى معنويا من مياه المجارى المعالجة ، الأمر الذى أدى الى زيادة ملوحة التربة في مختلف المواقع والمواسم كما احتوت الترب المروية بالمياه الجوفية على كميات مرتفعة من كاتيونات الكالسيوم والماغنسيوم والصوديوم والبوتاسيوم وكذلك أنيون الكبريتات مقارنة بالترب المروية بمياه المجارى. ولقد بينت النتائج إحتواء مصدرى المياه على كميات قليلة من الأمونيوم والنترات والحديد والمنجنيز والزنك والنحاس وبما يقل عن المستويات المسموح بها فى مياه الرى وأظهرت الدراسة أن الرى لمدة عشرون عاما بالمياه الجوفية للترب الموجودة بمنطقة الرياض أدى الى تمليح الترب وبالتالى كان له تأثير مثبط على أعداد الكائنات الحية الدقيقة التى تعيش فيها وعلي العكس من ذلك فإن الرى لنفس الفترة الزمنية بمياه المجارى المعالجة لم يكن له تأثيرات سلبية علي خواص الترب بل أدى الى زيادة نشاط أعداد كبيرة من ميكروبات التربة خاصة التى تلعب دور هام فى خصوبة التربة كميكروبات تثبيت النتيروجين الجوى وميكروبات التأزت وقد كان للرى بمثل هذه النوعية من المياه تأثير ضعيف علي أعداد ونشاط ميكروبات عكس التأزت والميكروبات المختزلة للكبريتات ويرجع ذلك لطبيعة قوام الترب فى هذه المنطقة (ترب رملية) حيث تسود الظروف الهوائية. وقد أكدت هذه الدراسة جودة مياه المجارى المعالجة وعلي ذلك يقترح البحث إمكانية استخدامها فى الأغراض الزراعية على نطاق كبير فى المملكة العربية السعودية خاصة في ري الأشجار الخشبية والغابات بالمنطقة الغربية وكذلك فى رى المسطحات الخضراء