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Ecological Study of Wadi Thulaim in Al-Kharj, Saudi Arabia

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ABSTRACT

The main objective of this study was to determine the impact of drainage water disposal on ecological parameters of Wadi Thulaim, Al-Kharj, Saudi Arabia. Water, sediment and plant samples were collected and analyzed for chemical characteristics. The dominant plant species were *Phragmites australis*, *Tamarix*, Bermuda grass and *Hamada elegans* in Wadi Thulaim. The drainage and sewage waters were classified as C4S1-C4S3 i.e., very high salinity and low sodium to very high salinity and high sodium hazards. The order of abundance of major cations was $\text{Na} > \text{Ca} > \text{Mg} > \text{K}$ and anions was $\text{Cl} > \text{SO}_4$ in the drainage and sewage waters. The order of abundance of various mineral elements in the plant tissues was $\text{K} > \text{Na} > \text{Ca} > \text{Mg}$ and that of anions was $\text{Cl} > \text{SO}_4$. The relationship between cations and anions in the drainage and sewage waters was poor. Also, the inter-ions relationship was very poor between the drainage waters and sewage waters. The trace elements and heavy metals concentration was very low. The Cl contents were considerably higher than SO_4 in Wadi sediment. Overall, Wadi sediments were dominant by Na and Cl ions. The nitrate (NO_3) contents in Wadi sediments were above the permissible limits, but very low in the drainage and sewage waters. Total salinity of Wadi sediments was high in certain locations. The concentration of TC (including total organic and inorganic carbon) ranged from 127.3-158.4 mg L^{-1} (drainage waters) and 151.90-251.50 mg L^{-1} (sewage water) in Wadi Thulaim. The NO_3 concentration of all the water samples was within the permissible limits of 30 mg L^{-1} for irrigation purpose.

Key words: Wadi Thulaim, sewage water, drainage water, sediments, plants, total water salinity, ion-inter-relationship, salinity and sodicity hazards, nitrate concentration

INTRODUCTION

Saudi Arabia is one of the biggest countries in the world with a total land area of 2.2 million square kilometers. It occupies about 4/5th of the Arabian Peninsula with great variations in climates, elevations, soil and vegetative characters. According to Al-Hinai (1989), sand dunes occupy about 1/4 of the total area of the Kingdom. Many ecological investigations such as those of Al-Yemeni and Al-Farraj (1995), Al-Farraj *et al.* (1997), Shaltout *et al.* (1997), Al-Yemeni (1997, 1998, 2000, 2001), Chaudhary (1999), Al-Yemeni and Zayed (1999), Taia and El-Ghanem (2001) and El-Ghanem (2006) have reported these variations. Also, these researchers studied the vegetation in different parts of Saudi Arabia and observed that climatic and edaphic factors (soil and substrate, topography, minerals, pH, substrates may be permanently or seasonally waterlogged, droughty, deficient in essential nutrients and extremely thin) largely affected the type

of vegetation communities and distribution in the country. Similar study was carried by El-Sheikh and Yousef (1981) who attributed the scattered vegetation in Al-Kharj to the combined effect of both the atmospheric and edaphic factors. Meanwhile, Al-Yemeni (2000) referred the differences in the structures of the vegetation to climatic aridity, topography, edaphic characters and human impacts.

Land topography is highly variable in Saudi Arabia consisting of mountains, hills, plateaus, plains, depressions and wades. As such, these land variations greatly affected the climate and vegetation. Also, the soil in wades is poor and can be considered Entisols, Inceptisols or Aridisols (Al-Nafea, 2004). Therefore, the differences in soil types and their characters caused considerable variations in plant communities in the wades in the Kingdom.

Study area: The study area was along Wadi Thulaim and extended up to 30 km with a width about 250-400 m at various locations in the Wadi. Its physical features vary greatly, become narrow and wider in some parts along the total course of whole Wadi (Fig. 1). Therefore, vegetation and the sediment characteristics were studied along the main drainage channel of Wadi.

Land disposal of waste effluents is an open threat to the environmental pollution especially in low land Wades in and around big cities in the Kingdom of Saudi Arabia. One of the major keys to solve these environmental issues is to study the quantity and quality of these waste effluents to determine ways and means for its safe disposal and reuse. Among different Wades in the Kingdom, Wadi Thulaim is located in the southern part of Al-Kharj city, Saudi Arabia. Al-Kharj is a city and governorate in central Saudi Arabia. The population of the governorate was 623,394 according to 2004 census. The city is located at around 24°8'54 N 47°18'18 E 24.14833°N 47.305°E.

According to the information [Personal communication, Director, Wastewater Treatment Plant (WTP), Al-Kharj], the sewage water/effluent received is around 120, 000 m³ day⁻¹ at the Wastewater Treatment Plant (WTP). The wastewater is composed of sewage water, industrial effluent and overflow of landscape irrigation in Al-Kharj city. Out of the total wastewater/effluent received at WTP, only 30, 000 m³ is treated by simple techniques such as removal of undesirable

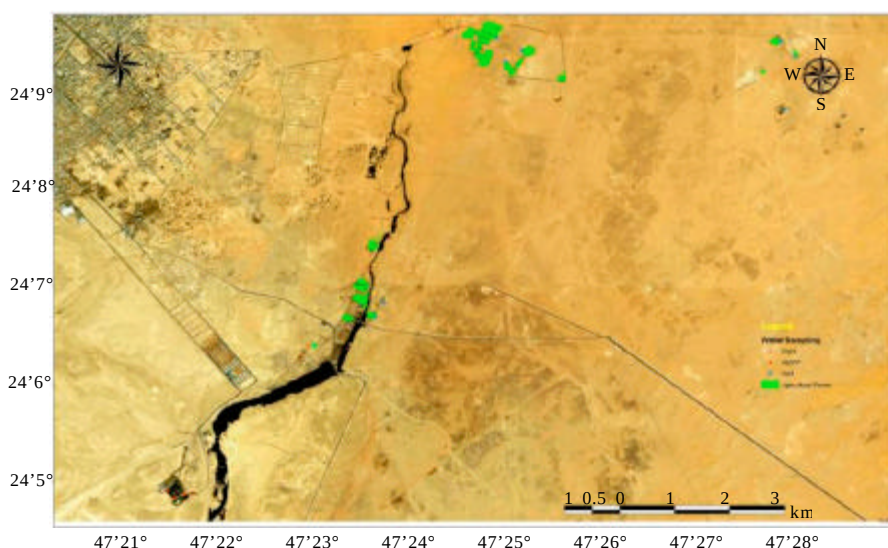


Fig. 1: Location map of drainage water, sediment and plants sampling in Wadi Thulaim, Al-Kharj

floating materials, sedimentation, aeration, chlorination and polymers application). The WTP, Al-Kharj simply determines the pH, Dissolved Oxygen (DO), total alkalinity (Alk), Chemical Oxygen Demand (COD), Biological Oxygen Demand (BOD) and Total Suspended Solids (TSS) of wastewater at the analytical facility of WTP. The wastewater from the city is collected at WTP and is allowed to flow into the Wadi treated and untreated. It is well known that wastewater contains organic, inorganic and biological pollutants to various degrees. As such disposal of wastewater in a Wadi can alleviate environmental and health hazards. It is, therefore, imperative to study the quality of wastewater from Al-Kharj city and determine its chemical properties in order to develop applicable management strategies for its reuse and to minimize environmental pollution resulting from its land disposal in Wadi drainage channel. The main objectives of this study were (1) To evaluate the chemistry of drainage water and sewage wastewater in Wadi (2) To Determine the chemistry of sediments from Wadi drainage channel of Wadi Thulaim and (3) To find different plant communities in the main drainage channel of Wadi.

MATERIALS AND METHODS

The study was carried to determine the impact of land disposal of drainage water from Al-Kharj City on ecological parameters of Wadi Thlaim, Al-Kharj during 2009.

Collection of drainage and sewage water samples: A total of seven drainage water samples (labeled as KS-1 to KS-7) were collected from main Wadi drainage channel. The samples were collected in one liter sterile plastic bottles, stored in an ice box and transported to analytical laboratory of National Center for Water Technology (NCWT), King Abdulaziz City for Science and Technology (KACST), Riyadh for analysis. Also, nine sewage water samples (labeled as S-1 to S-9) were collected from Wastewater Treatment Plant (WTP), Al-Kharj for analysis. The sampling locations for water, sediment and plants are shown in Fig. 1.

Collection of sediment samples: Sediment samples from Wadi bed were collected from 0-30 cm depth by a hand auger. The sediment samples were air-dried, passed through 2mm sieve and stored for chemical analysis. These samples were analyzed for pH, E_{Ce}, total cations and anions, trace elements and heavy metals.

Collection of plant samples: Plant samples were collected from the main Wadi drainage channel from different locations from the same place where the sediment samples were collected. Plant Communities in drainage channel of Wadi Thulaim are shown in Fig. 2. Plant samples were oven-dried at 65°C to a constant weight, ground in a Coffee grinder to powdery form and then stored for analysis. The plant samples were analyzed for all cations, trace and heavy metals.

Water, sediment and plant analysis: All the three types of samples (waters, sediments and plants) were analyzed by following standard analytical methods according to USDA (1954) and APHA, AWWA and WEF (1995).

Data analysis: Data were analyzed by ANOVA and regression techniques for treatment evaluation at 5% level of significance according to SAS Institute (2001).



Fig. 2: Plant communities in drainage channel of Wadi Thulaim

Table 1: Chemical composition of drainage and sewage waters in Wadi Thulaim, Al-Kharj

	EC		Adj	Adj	HCO3		Ca	Mg	Na	K	Cl	SO4	NO3	PO4		
ID	pH	(dS m ⁻¹)	SAR	RNa	SAR	ESP (mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	(mg L ⁻¹)	TDS	
KS1	8.10	3400	5.46	6.93	14.65	6.36	320	208	85	370	40	510	697	5.1	0.00	2173
KS2	7.50	3400	5.46	6.96	14.68	6.36	330	206	83	367	42	502	693	2.5	2.85	2178
KS3	7.50	3100	5.62	7.12	14.78	6.57	320	184	73	356	39	445	655	2.3	3.20	2017
KS4	7.50	3100	5.27	7.04	14.05	6.12	330	215	63	342	31	439	648	2.6	2.86	1970
KS5	7.50	3100	6.35	8.59	16.55	7.49	336	194	49	382	41	441	630	2.2	2.49	2011
KS6	7.30	3090	6.11	8.32	16.09	7.20	341	203	51	376	40	461	621	2.4	2.32	2005
KS7	7.30	3100	4.84	6.71	13.08	5.55	342	240	58	322	41	452	637	2.4	2.51	2013
S1	-	3520	7.72	11.00	20.13	9.19	480	140	29	384	35	341	445	13.0	0.00	1760
S2	-	3120	6.10	7.97	15.30	7.18	360	132	38	309	32	330	412	3.2	34.40	1560
S3	7.60	2500	4.14	5.26	10.92	4.63	344	164	68	250	23	352	448	8.6	0.00	1587
S4	7.60	2600	3.85	4.73	10.31	4.24	332	168	90	249	24	391	499	10.2	0.00	1702
S5	7.60	2600	4.24	5.47	11.04	4.76	320	176	61	256	42	392	463	2.9	0.00	1658
S6	7.20	3700	4.49	5.86	11.84	5.10	348	178	58	270	45	348	522	3.1	0.00	1711
S7	7.40	2700	4.71	6.45	12.50	5.38	380	181	48	276	26	399	383	2.8	0.00	1621
S8	7.60	2600	3.99	5.22	10.77	4.42	390	174	65	243	33	351	430	2.6	0.00	1010
S9	7.40	2600	4.58	5.89	11.90	5.20	328	169	60	272	42	392	462	3.1	0.00	1660

RESULTS AND DISCUSSION

Chemistry of drainage waters: Different chemical parameters in drainage water of Wadi channel ranged between 7.3-8.1 (pH), 3.09-3.40 (EC, dS m⁻¹), 1970-2178 mg L⁻¹ Total Dissolved Solids (TDS), 4.84-6.35 sodium adsorption ratio (SAR) 6.71-8.59 (adj.RNa), 13.08-16.55 (adj.SAR) and 5.55-7.49 [predicted exchangeable sodium percentage (ESP)] at different locations in Wadi Thulaim (Table 1). The drainage waters were classified as C4S1-C4S3 i.e., very high salinity and low sodium to very high salinity and high sodium category waters according to water classification scheme of Ayers and Westcot (1985) and USDA (1954).

Chemistry of sewage waters at wastewater treatment plant (WTP): The ranges for different chemical parameters of sewage water received at the Wastewater Treatment Plant, Al-Kharj were

7.2-7.6 (pH), 2.50-3.70 (EC, dS m⁻¹), 1010-1760 mg L⁻¹ Total Dissolved Solids (TDS), 3.85-7.72 Sodium Adsorption Ratio (SAR) 4.73-11.00 (adj.R_{Na}), 10.31-20.13 (adj.SAR) and 4.24-9.19 predicted exchangeable sodium percentage (ESP) (Table 1). The wastewater received at the treatment plant was classified as C4S1-C4S2 i.e., very high salinity and low sodium to very high salinity and high sodium waters according to water classification scheme of Ayers and Westcot (1985) and USDA (1954).

Relationship between EC and different SAR's: The relationship between EC and different SAR's of drainage waters is very poor (R^2 values of 0.013, 0.168 and 0.0333 for adj.SAR, adj. RNa and SAR, respectively) at different locations of Wadi Thulaim (Fig. 3). However, It is interesting to note that the SAR values showed slight decreases with increasing total water salinity.

On the other hand, relationship between EC and SAR's of sewage water was slightly higher as compared to the drainage waters with R^2 values of 0.414, 0.408 and 0.411 for adj. SAR, adj. RNa and SAR, respectively (Fig. 4). The slight increase in sodicity may be due to the precipitation of Ca ion as calcium carbonate due to the release of more CO₂ by the oxidation of carbonaceous materials (organic compounds) in sewage water during aeration step.

Relationship between SAR vs adj. R_{Na} and adj. SAR: A strong relationship was found between the SAR and adj.SAR ($R^2 = 0.993$) and adj.RNa ($R^2 = 0.869$) of drainage water. The predicted soil

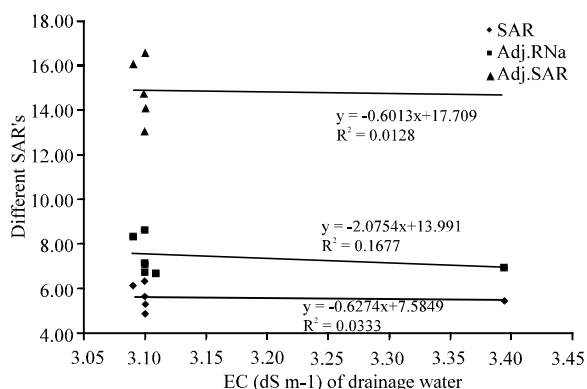


Fig. 3: Relationship between EC and SAR's of drainage waters

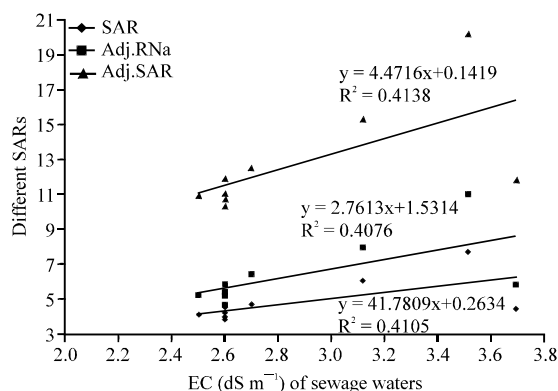


Fig. 4: Relationship between EC vs SAR's of sewage water, Al-Kharj

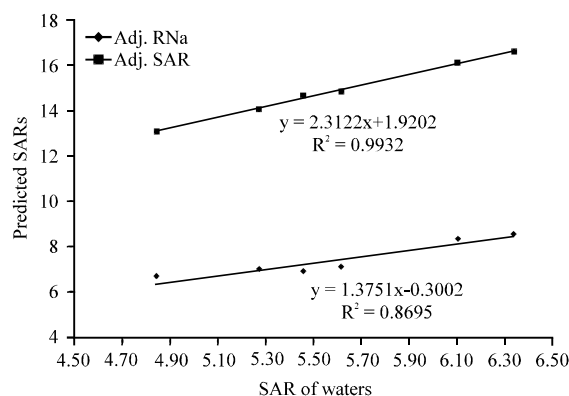


Fig. 5: Relationship between SAR and Adj. Rna. SAR of drainage waters

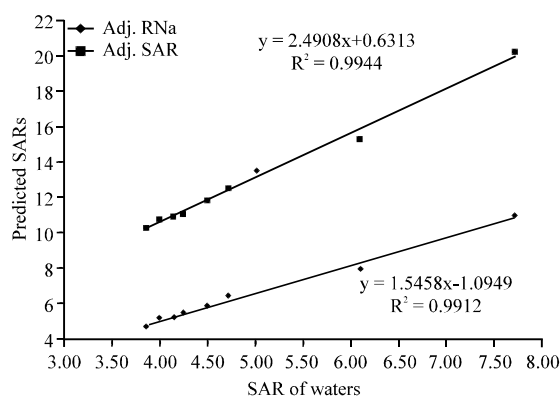


Fig. 6: Relationship between SAR and Adj. Rna. SAR of sewage waters

sodicity hazards may be higher by adj.SAR than adj. RNa of drainage waters (Fig. 5). Overall, data showed that there may be little possibility of soil sodicity problems after irrigation, as the values of predicted SAR's are within the upper limits of SAR of irrigation waters 15 for developing the soil sodicity hazards according to the criterion established by USDA (1954).

The regression analysis showed a strong relationship between SAR vs adj.SAR ($R^2 = 0.994$) and SAR vs adj. RNa ($R^2 = 0.991$) of sewage waters (Fig. 6). In general, the SAR values of the sewage water are slightly higher than those of drainage waters. There is a possibility that soil sodicity hazards may develop if reused for irrigation. Overall, the sequence for developing soil sodicity hazards, if any, is sewage waters>drainage waters.

INTER-IONS-RELATIONSHIP

Drainage waters: The regression analysis showed poor relationship between Na and Cl ion ($R^2 = 0.011$), Na and SO_4 ion ($R^2 = 0.096$) (Fig. 7), Mg vs SO_4 ($R^2 = 0.002$), Mg vs Cl ($R^2 = 0.037$) (Fig. 8), Ca vs Cl ($R^2 = 0.204$) and Ca vs SO_4 ($R^2 = 0.006$) (Fig. 9) of the drainage waters in Wadi Thulaim.

Sewage water: A very poor relationship was found between Na and Cl ion ($R^2 = 0.199$), Na and SO_4 ($R^2 = 0.046$) (Fig. 10), Mg vs SO_4 ($R^2 = 0.259$) and Mg vs Cl ($R^2 = 0.224$) (Fig. 11), Ca vs Cl

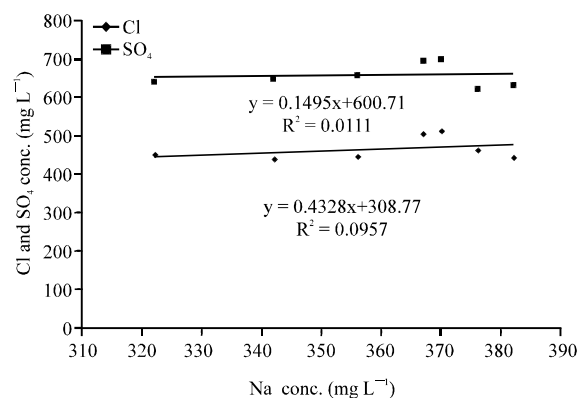


Fig. 7: Relationship between Na vs Cl and SO₄ of drainage waters

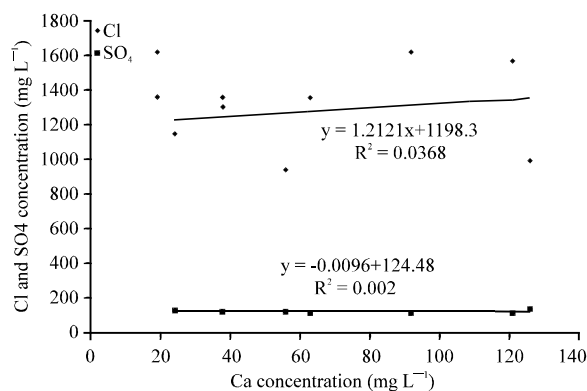


Fig. 8: Relationship between Mg vs Cl and SO₄ of drainage waters

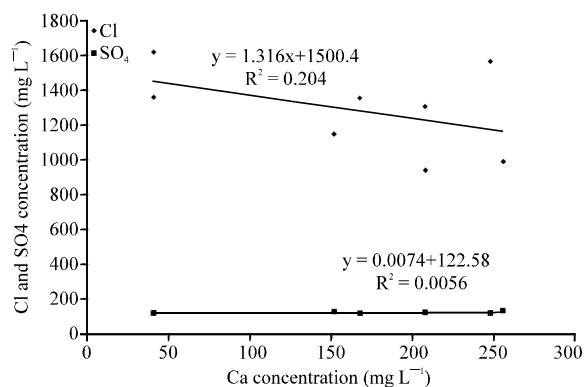


Fig. 9: Relationship between Ca vs Cl and SO₄ of drainage waters

($R^2 = 0.443$) and very poor between Ca vs SO₄ ($R^2 = 0.059$) (Fig. 12) of sewage water at Wastewater Treatment Plant (WTP) Al-Kharj in Wadi Thulaim. The results also showed low concentration of all the cations/anions in sewage water as compared to drainage waters. This may be due to the fact that the main source of wastewater received at the WTP, Al-Kharj is the sewage effluent from houses, hospitals, industries, laundries and other localities which use potable water.

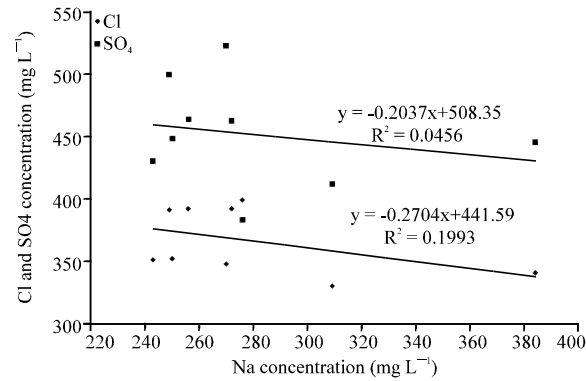


Fig. 10: Relationship between Na vs Cl and SO₄ of drainage waters

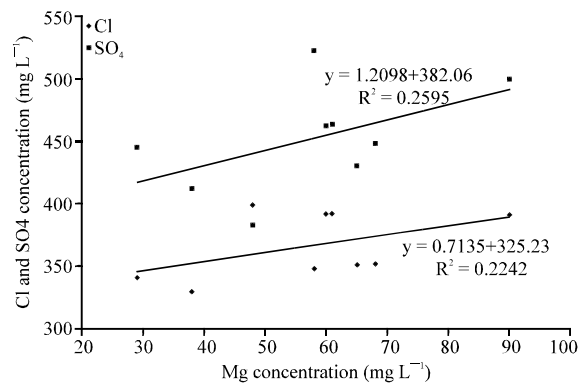


Fig. 11: Relationship between Mg vs Cl and SO₄ of drainage waters

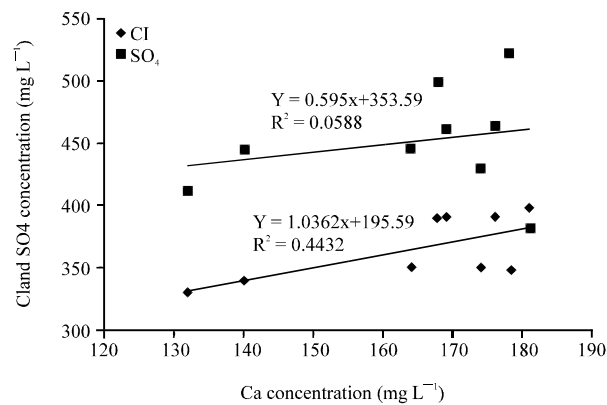
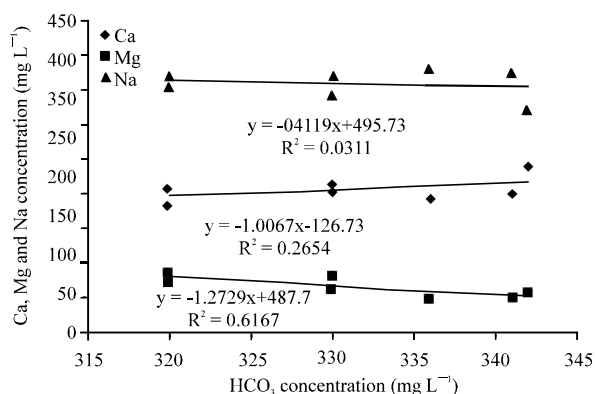
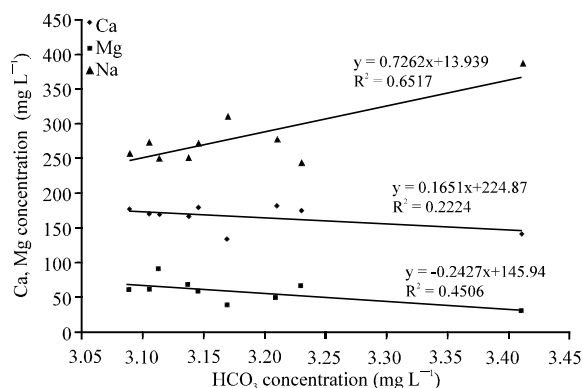


Fig. 12: Relationship between Ca vs Cl and SO₄ of drainage waters

HCO₃ relationship with cations: The relationship was poor between HCO₃ and Ca ($R^2 = 0.265$) and, HCO₃ and Na ($R^2 = 0.031$), but was high and negative between HCO₃ and Mg ($R^2 = 0.617$) in the drainage water samples (Fig. 13). It was observed that Mg concentration in the drainage waters decreased with increasing HCO₃ concentration. This may be attributed to precipitation of

Fig. 13: Relationship between HCO_3^- vs Ca, Mg of drainage watersFig. 14: Relationship between HCO_3^- vs Ca, Mg and Na of sewage water

MgCO_3 with high HCO_3^- contents of drainage water resulting from dissolution of carbonate minerals from Wadi sediments. In the case of sewage water, relationship was poor between HCO_3^- and Ca ($R^2 = 0.222$) and, HCO_3^- and Mg ($R^2 = 0.451$), but was comparatively better between HCO_3^- and Na ($R^2 = 0.652$) (Fig. 14). The results indicated that there seems to be excessive use of sodium-based detergents and washing liquids/powders in houses, hospitals, laundries and industries for cleaning and processing of different products.

Total carbon (TC): The concentration of TC (including total organic and inorganic carbon) ranged from 127.3-158.4 mg L^{-1} (drainage waters) and 151.90-251.50 mg L^{-1} (sewage water) in Wadi Thulaim (Table 2). Data showed that the carbonaceous compounds are considerably higher in the raw sewage water as compared to the drainage waters. The sequence for the abundance of TC concentration followed the pattern as sewage water > drainage water. The decrease in TC in the drainage water may be attributed to oxidation of organic compounds due to water turbulence in the drainage channel depending on the flow rate of water and the slope of the Wadi drainage channel.

Trace and heavy metal concentration: The concentration of all the trace and heavy metals is very low in drainage waters of Wadi Thulaim and the sewage water received at WTP, Al-Kharj

Table 2: Trace elements and heavy metal ions (mg L⁻¹) in drainage and sewage waters of Wadi Thulaim, Al-Kharj

ID	As	Co	Cr	Cu	Mn	Mo	Ni	Pb	Zn	TC
KS1	0.013	0.009	0.004	0.006	0.006	0.006	-	0.002	0.018	127.3
KS2	0.015	0.009	0.006	0.006	0.008	0.006	0.003	0.015	0.024	157.6
KS3	0.016	0.009	0.005	0.006	0.009	0.007	0.02	0.014	0.021	158.4
KS4	0.018	0.009	0.005	0.006	0.009	0.006	0.001	0.004	0.023	155.2
KS5	0.010	0.009	0.006	0.008	0.057	0.006	-	0.006	0.045	156.4
KS6	0.008	0.008	0.004	0.006	0.024	0.007	-	0.014	0.058	150.7
KS7	0.007	0.009	0.005	0.009	0.026	0.006	0.003	-	0.037	151.7
S1	0.004	0.009	0.003	0.019	0.028	0.011	0.002	-	0.156	251.5
S2	0.005	0.010	0.005	0.008	0.015	0.007	0.004	-	0.031	230.1
S3	0.012	0.009	0.007	0.008	0.045	0.006	0.003	0.002	0.023	182.9
S4	0.003	0.008	0.006	0.006	0.013	0.006	0.002	-	0.019	165.1
S5	0.007	0.008	0.005	0.005	0.051	0.006	0.003	-	0.022	172.9
S6	0.008	0.008	0.010	0.006	0.030	0.007	0.006	-	0.008	159.7
S7	0.005	0.009	0.009	0.006	0.041	0.006	0.005	0.023	0.016	151.9
S8	0.007	0.009	0.009	0.006	0.021	0.006	0.007	-	0.002	153.9
S9	0.003	0.008	0.004	0.006	0.009	0.006	0.001	-	0.023	155.2
Permissible limits (Ayers and westcot (1985))	0.100	0.050	0.100	0.200	0.200	0.010	0.200	5.0000	2.000	

(Table 2). Furthermore, the concentration of all the elements determined is less than the maximum permissible limits for agriculture use according to Ayers and Westcot (1985). Therefore, the presence of these different trace and heavy metals in wastewaters in Wadi Thulaim do not seem to pose any serious environmental hazards if intended for reuse in agriculture.

Nitrate (NO₃) concentration: The NO₃ concentration ranged from 2.2-5.1 mg L⁻¹ in drainage waters and 2.6-13.0 mg L⁻¹ in sewage water of WTP, Al-Kharj (Table 1). Overall, the NO₃ contents in all the water samples (drainage and sewage water) is within the permissible limits of 30 mg L⁻¹ for safe use of irrigation according to Ayers and Westcot (1985) and APHA (1998).

Phosphate (PO₄) concentration: The PO₄ contents were not detected in the sewage effluent of WTP, Al-Kharj (except the raw waste effluent entering the WTP), but the PO₄ contents in drainage waters ranged from 2.32-3.20 mg L⁻¹ (Table 1). Besides, the raw waste effluent entering the WTP, Al-Kharj contained 34.4 mg L⁻¹ of PO₄. The only possibility of high PO₄ contents in the sewage effluent may be due to excessive use of phosphorus based detergents or other liquids in houses, hospitals, laundries and chemical industries.

Chemical composition of plants: Main plant communities found along main drainage channel of Wadi Thulaim were Tamarix, Phragmites australis, Bermuda grass and Hamada elegan. Chemical composition of different plants such as Phragmitus australis, tamarix, Hamada elegan and Bermuda grass is presented (Table 3). The order of abundance of major mineral elements in different plants was K>Na>Ca>Mg while for anions Cl>SO₄. The Nitrate (NO₃) contents ranged between 82-1410 mg L⁻¹ in different plants. Overall NO₃ concentration was high in Phragmites australis followed in descending order by Bermuda grass>Hamada elegan>Tamarix (Table 3). The concentration of various trace elements and heavy metals such as Mn, Fe, Cu, Zn, Ni, Co, Pb, Cd and Cr was very low (Table 4).

Table 3: Chemical composition of plants from Wadi Thulaim, Al-Kharj

Sample No.	Ca	Mg	Na	K	Cl	SO ₄	NO ₃	F	PO ₄
	------(%)-----						------(mgL ⁻¹)-----		
KS1 (<i>P. Australis</i>)	3.9	1.3	8.62	1.58	2.24	17.86	42	0.58	--
KS2 (<i>B. Grass</i>)	3.46	2.18	18.44	7.60	3.54	4.62	84	2.6	--
KS3a (<i>Tamarix</i>)	1.04	0.3	1.98	6.34	3.36	3.44	40	2.9	--
KS3b (<i>P. Australis</i>)	0.44	0.08	1.88	9.40	6.16	5.80	64	2.81	--
KS4 (<i>H. Elagan</i>)	5.20	2.82	0.36	1.24	3.00	27.10	50	6.8	--
KS5 (<i>P. Australis</i>)	0.70	0.02	0.82	7.46	2.42	6.50	24	3.16	--
KS6 (<i>P. Australis</i>)	0.40	0.044	0.48	8.72	2.48	6.20	192	9.3	--

Table 4: Trace elements and heavy metals composition of plants from Wadi Thulaim, Al-Kharj

Sample No.	Mn	Fe	Cu	Ni	Co	Zn	Pb	As	Cd	Cr
	------(mg L ⁻¹)-----									
KS1 (<i>P. Australis</i>)	1.87	5.2	0.12	0.028	0.017	0.19	0.028	--	--	0.26
KS2 (<i>B. Grass</i>)	0.26	2.90	0.072	0.021	0.010	0.16	0.014	--	--	0.008
KS3a (<i>Tamarix</i>)	0.39	3.7	0.084	0.019	0.011	0.13	0.013	--	0.07	0.007
KS3b (<i>P. Australis</i>)	0.14	2.1	0.061	0.021	0.004	0.1	0.012	--	--	0.011
KS4 (<i>H. Elagan</i>)	0.18	1.8	0.079	0.013	0.008	0.08	0.008	--	--	0.008
KS5 (<i>P. Australis</i>)	0.13	1.4	0.062	0.015	0.007	0.12	0.012	--	--	0.005
KS6 (<i>P. Australis</i>)	0.29	1.3	0.041	0.12	0.006	1.13	0.014	--	--	0.009

Classification of drainage waters: Drainage and sewage waters were classified according to water classification schemes of Ayers and Westcot (1985) and USDA (1954) for irrigation purposes and fall in the category of C4S1 to C4S3 i.e., waters of very high salinity and low sodium to very high salinity and high sodium class (Fig. 15). Some of these waters may develop high soil salinity and sodicity problems after crop irrigation which can be mitigated by following certain management practices such as application of leaching requirements at least 15% in excess of crop water requirements to control salt build up in soils, selection of semi-salt tolerant crop species and adoption of alternate irrigation methods (one irrigation with fresh water followed by irrigation with saline water) and improved irrigation systems. In order to avoid the soil sodicity problems, application of gypsum will be required to minimize the hazards of sodium in the wastewaters.

Classification of drainage waters for soil infiltration hazards: Data in Fig. 16 indicate that all these waters will not create any soil infiltration problems. Because high water salinity along with high sodium contents improves the soil physical structure rather than soil dispersion. Because at low concentration, hydrolysis of salt takes place and seals the macro pores due to flocculating colloid particles thus affecting the soil infiltration rate.

Wadi sediments: The chemical parameters of sediments in Wadi drainage channel ranged from 7.69-8.64 (pH), 4.63-79.10 (EC_e dS m⁻¹), 171-3394 mg L⁻¹ (Ca), 72-2064 mg L⁻¹ (Mg), 732-10312 mg L⁻¹ (Na), 32-455 mg L⁻¹ (K), 918-20944 mg L⁻¹ (Cl), 755-3478 mg L⁻¹ (SO₄), 49-7343 mg L⁻¹ (NO₃), 0.54-1.39 mg L⁻¹ (F) and 240-580 mg L⁻¹ (HCO₃) at different locations in Wadi Thulaim (Table 5). The order of abundance for cations is Na>Ca>Mg>K and that of anions is Cl>SO₄ in the sediments of Wadi Thulaim, Al-Kharj. However, the total

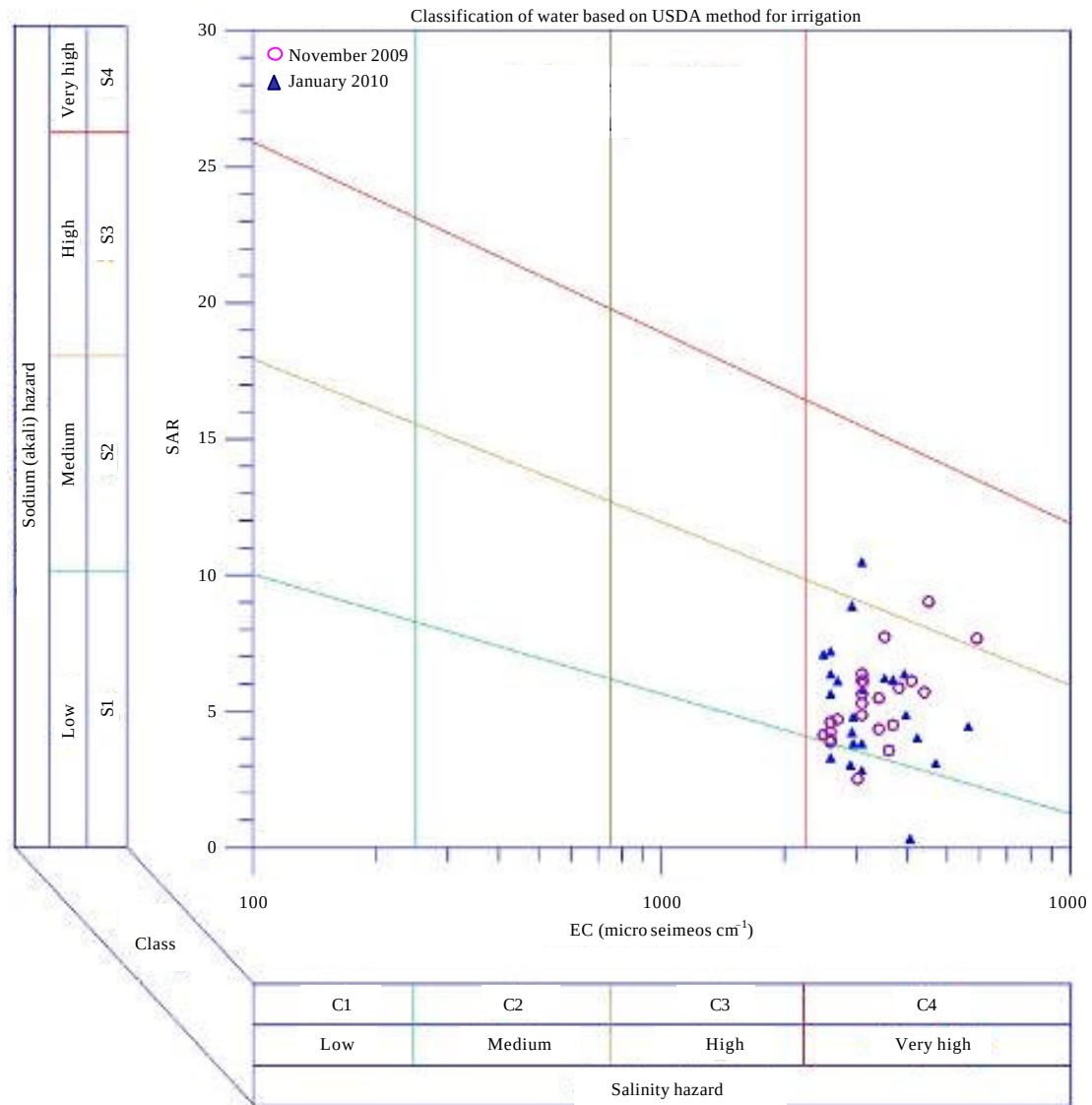


Fig. 15: Classification of drainage waters of Wadi Thulaim for agriculture use according to water classification scheme of USDA (1954) and FAO (1985)

Table 5: Chemical composition of sediments from main drainage channel of Wadi Thulaim, Al-Kharj

Sr. No.	pH	EC (dS m ⁻¹)	TDS	HCO ₃	Ca	Mg	Na	K	Cl	SO ₄	NO ₃	F	PO ₄	T.Alk.
----- (mg L ⁻¹) -----														
KS-1	7.69	79.10	59780	580	3394	2064	10312	111	20944	3478	7343	1.39	--	475
KS-2	8.53	7.96	4930	248	314	192	1123	14	1543	1498	99	0.82	--	203
KS-3	8.29	16.97	10540	436	782	260	2210	455	3652	2171	784	1.05	--	357
KS-4	8.64	4.63	2860	248	163	72	732	32	918	760	49	0.58	--	203
KS-5	8.26	4.76	3020	240	171	79	764	47	1022	755	53	0.54	--	197
KS-6	7.76	10.44	6540	372	421	192	1469	210	2275	1512	256	0.91	--	305

salinity of sediment samples 01, 03 and 06 is very high than other samples which may be due to the high salt contents of the outcrop in the vicinity of main drainage channel. The Cl

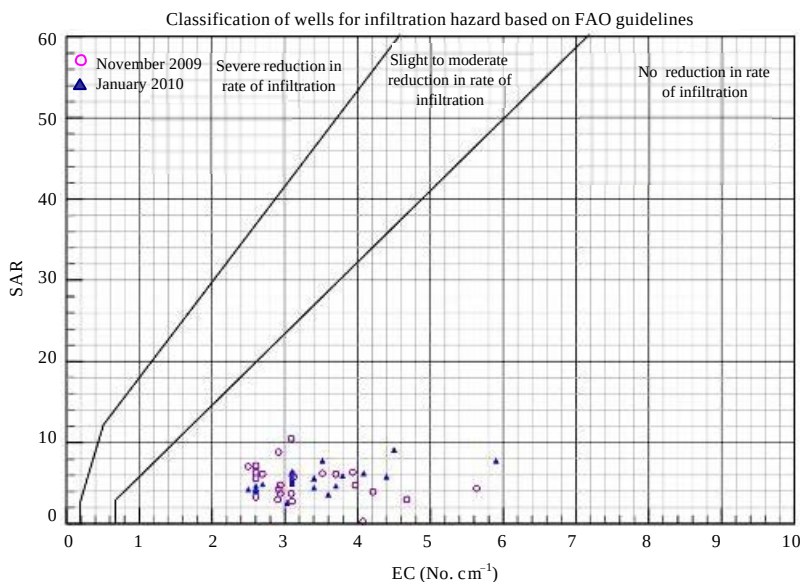


Fig. 16: Classification of drainage waters from Wadi Thulaim for soil infiltration hazards based on FAO (1985)

Table 6: Trace elements and heavy metal concentration in sediments of drainage channel of Wadi Thulaim, Al-Kharj

Sr. No.	As	Cu	Co	Cd	Cr	Ni	Pb	Zn
	(mg L ⁻¹)							
KS-1	4.94	12.1	0.32	0.11	-	11.16	4.80	1.80
KS-2	1.98	-	0.024	0.05	-	0.612	-	0.20
KS-3	2.85	-	0.26	0.08	-	1.33	3.61	0.24
KS-4	1.52	-	0.07	0.023	-	10.93	-	0.20
KS-5	1.54	1.2	0.022	0.08	-	3.02	-	0.19
KS-6	2.05	-	0.027	0.07	-	2.13	-	0.26

contents were much higher than SO₄ ion in Wadi sediment. Overall, Na and Cl ions dominate the chemical composition of Wadi sediments.

The trace elements and heavy metal concentration (mg L⁻¹) ranged from 1.52-4.94 (As), 1.2-12.1 (Cu), 0.022-0.32 (Co), 0.05-0.11 (Cd), 0.612-11.16 (Ni), 3.61-4.8 (Pb) and 0.20-1.80 (Zn) at different locations in the Wadi sediments (Table 6).

CONCLUSION

The dominant plant species were *Phragmites australis*, *Tamarix*, Bermuda grass and *Hamada elegans* in the drainage channel of Wadi Thulaim. The drainage and sewage waters were classified as C4S1-C4S3 i.e., very high salinity and low sodium to very high salinity and high sodium hazards. The order of abundance of major cations was Na>Ca>Mg>K and for anions was Cl>SO₄ in drainage and sewage waters. The regression analysis showed very poor relationship between cations and anions in the drainage and sewage waters. The inter-ions relationship was very poor in both the drainage waters and sewage waters. The trace elements and heavy metals concentration was very low. Overall, the NO₃ contents in all the water samples (drainage and sewage water) were within the permissible limits of 30 mg L⁻¹ for irrigation purpose. The nitrate (NO₃) concentration was above the permissible limits in Wadi sediments. Total salinity of sediment was high at certain locations.

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