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Assessment of Groundwater Salinization and Soil Degradation in Abdally Farms, Kuwait

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تقييم ملوحة المياه الجوفية وتدهور التربة في مزارع العبدلي

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خلاصة: تقع دولة الكويت ضمن نطاق المناخ الجاف وتعتمد بشكل أساسي على محطات تحلية البحر لتغطية الطلب على مياه الشرب. وبالمقابل فإن حوالي ١٠٠٠٠٠ متر مكعب من المياه قليلة الملوحة تنتج سنوياً من الخزانات الجوفية (صخور مجموعة الكويت وطبقات تكوين الدمام). وتستخدم هذه المياه بشكل رئيسي للخلط مع مياه البحر المقطرة بنسبة تقدر ما بين ٥-١٠%، ويستخدم الجزء الباقي من المياه الجوفية لري المحاصيل الزراعية. وقد هدفت هذه الدراسة إلى تقييم أثر استخدام المياه الجوفية قليلة الملوحة في الري على التربة وعلى مخزون المياه الجوفية. ولذلك فقد تم جمع ١٥٠ عينة ممثلة للمياه الجوفية وللتربة من ٢٥ مزرعة مختارة، ومن ثم تم إجراء التحاليل الكيميائية والفيزيائية لهذه العينات. وقد خلصت الدراسة إلى وجود علاقة مباشرة و طردية بين نوعية المياه الجوفية وارتفاع ملوحة التربة والتي دلت المعلومات بأنها بازدياد منذ تأسيس منطقة العبدلي الزراعية. ويمكن إيعاز ذلك إلى عدم إدارة موارد المياه الجوفية بشكل صحيح وعدم استخدامها بكفاءة. وقد أوصت هذه الدراسة باستخدام مياه الصرف الصحي المعالجة ثلاثياً للأغراض الزراعية للحصول على تنوع واسع من المحاصيل، ولمنع تدهور التربة ومخزون المياه الجوفية في نفس الوقت.

ABSTRACT: Kuwait is a part of the arid and semi arid region, where irrigation is necessary for any realistic agricultural activities. There are no surface fresh water resources in Kuwait. Fresh water is provided from desalination of seawater. However, this water is used mainly for potable purposes. A total of 100,000 cubic meters of brackish groundwater is annually produced from the Kuwait Group and Dammam Formation aquifers. This water is mainly used for mixing at 5–10% with distilled water and for irrigation of specific crops. The aim of this study was to assess the impact of brackish groundwater irrigation on groundwater and soil. A total of 161 water and soil samples from 25 selected farms were collected and analyzed for chemical and physical parameters. It was concluded that soil salinity was directly proportional to that of groundwater and a high increase in soil salinity was recognized since the establishment of the farms in Abdally. That was mainly related to the mismanagement of groundwater resources, which causes soil degradation in addition to the losses and inefficiency in water usage. It is recommended to use tertiary treated wastewater for irrigation activities in order to have a wider range of crops to be grown and to prevent the deterioration in both soil and groundwater resources.

Keywords: Arid, irrigation, aquifers, wastewater.

Salinity problems are generally more pronounced in arid and semi-arid regions because there is not sufficient annual rainfall to flush salts from the crop-rooting zone. In such areas, an additional problem arises from the combination of high evaporation and the shallow depth of groundwater. The main source of salts in soils, such as those in Kuwait, are weathering of fossil salts and groundwater, which brings up and redistributes its soluble contents on the ground surface. Deterioration in the quality of groundwater, especially increases in its salinity and sodicity, will exasperate soil problems, which intensify the pressure to use more water, thus damaging both the water and soil resources. The essential concern in farming practices in arid and semi-arid regions is to maintain soil moisture at the lowest possible stress level for growing plants. This is accomplished through controlled irrigation schemes and within the constraints imposed by soil properties and water quality.

Soil moisture stress is a function of interactions between osmotic potential, which is proportional to the salt concentration in the soil water, and soil matrix

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potential, related to soil texture and the amount of irrigation water applied (Rhoades, 1987). To control these stress factors appropriate leaching should be used to achieve downward salt transport out of the root zone as means to bring osmotic pressure to the lowest practical level. In addition, soil moisture should be maintained at levels that can lead to the maximum crop yield potential. Irrigation technologies, methods and frequency of application, leaching requirements and adequate drainage are the keys to successful and sustainable exploitation of water and soil resources (Mashali, 1997). The aim of this study was to assess the impact of brackish groundwater irrigation on groundwater and soil.

Materials and Methods

The collection of groundwater and soil samples from the selected farms in the Abdally area in the northeastern corner of Kuwait was the first step towards the goals of this study. Figure 1 shows the location of the study area. The sampling activities were conducted in summer and winter to take into consideration the seasonal weather variations. Collection and preservation of representative groundwater samples was carried out in accordance with standard operating procedures. During the winter season, 42 groundwater samples were collected from 25 selected farms. In summer, there were no reference samples (non-irrigated) and 24 groundwater samples were collected. Using the peak salinity tests, 71 soil samples out of 335 collected samples in the winter season were selected for further laboratory analysis. The peak salinity tests were conducted by collecting soil samples for each 20 cm of the root zone, testing its extract in the laboratory for salinity and selecting the most saline soils extracts. During the summer season, reference soil samples were not collected because change in soil quality was not expected to be encountered without the application of irrigation water. A total of 24 soil samples were collected. The collected groundwater and soil samples were analyzed in the field and the laboratory for chemical and physical characters. The groundwater and soil samples were analyzed for electrical conductivity (EC), soluble cations and anions, boron (B), and hydrogen-ion activity (pH). On the basis of the results of the analyses, soil types were classified in the study area.

Results and Discussion

GROUNDWATER: Groundwater suitability for irrigation is contingent upon the expected effects of the water on both the plants and the soil. Saline soils may harm plant growth physically by limiting the uptake of water through modification of osmotic processes, or chemically by metabolic reactions such as those caused by toxic constituents (Todd, 1980). The pH average values for all the collected samples during both winter and summer seasons were considered neutral and mostly around 7.3, rarely going above 8.0 or below 6.0 at 25^{O}C. Groundwater

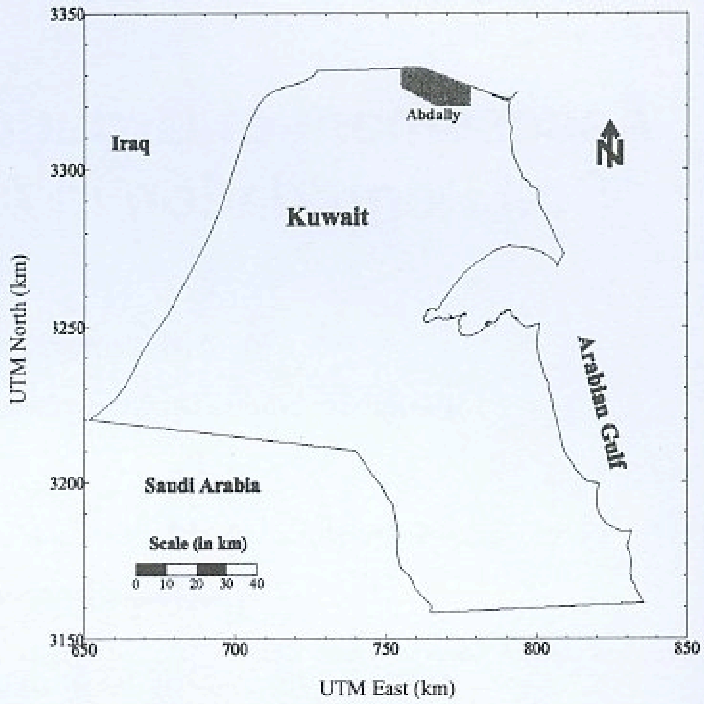

Figure 1. Location map of the Abdally farming area.

reached its maximum salinity (17,500 mg/l) in winter, which reflects the effect of return flow from the irrigation practices as winter is the main cultivation season. Additionally, the over pumping in this season leads to rising of more saline water in the pumped aquifer. Carbonate concentrations were negligible, and bicarbonate range was normal and varied between 69 and 210 mg/l. Table 1 presents the summary of summer and winter groundwater analyses. The increase in sulfate and chloride during the winter was due to the natural leaching process because of the increase in irrigation practices. The increase in boron concentration in summer may be due to the distribution of evaporite deposits as a result of high evaporation rates and low rainfall. Boron concentrations within the Abdally area were within the safe limits for irrigation (< 1.0 mg/l). Sodium average concentration increased in summer as a result of an increase in evaporation. Potassium concentrations were much lower than sodium and almost the same in winter and summer. This was also noticed for calcium; the average concentration for both seasons was 540 mg/l.

TABLE 1

Summary of groundwater analyses in the Abdally area.

Parameter mg/l	Summer		Winter	
	Maximum	Minimum	Maximum	Minimum
TDS	14900	5700	17500	5200
HCO_3^-	186	85	210	69
SO_4^{2-}	3854	1168	4437	1320
Cl^-	5855	1582	6136	1050
B	1	0	1	0
Na^+	4263	994	5857	920
K^+	33	1	31	8
Ca^{2+}	759	42	771	308
Mg^{2+}	33	9	20	7

TABLE 2

Summary of soil extracts analyses in the Abdally area.

Parameter mg/l	Summer		Winter	
	Maximum	Minimum	Maximum	Minimum
SO_4^{2-}	7485	2459	4963	2
Cl^-	6424	765	5558	30
B	2	0	1	0
Na^+	6512	1407	4274	4
K^+	360	11	360	8
Ca^{2+}	1018	267	1210	40
Mg^{2+}	34	2	54	0

This could suggest that solubility products of the aquifer material control the concentration of potassium and calcium. Magnesium concentrations were greater during summer and that could be due to excess leaching of soil during winter irrigation, through which magnesium ions are forced to leave high exchange capacity surfaces.

SOIL: Soil salinity, represented by the EC of soil extracts, varied between 5 and 25 dS/m. It increased in the irrigated soil, which is an indication of the effect of irrigation with brackish water since the establishment of the farming area. Soil salinity coincided with the groundwater salinity of the study area, which increases towards the northwest and southeast. There was no systematic relation between soil salinity and depth of the water table. Table 2 shows the summary of the soil extract analyses during winter and summer seasons. Carbonate and bicarbonate concentrations were negligible. Sulfate and chloride concentrations were higher in irrigated areas and within these areas they were higher in summer owing to high evapotranspiration rates. This leaves the return flow with higher concentration of sulfate and chloride. Sodium concentration was also higher in the irrigated areas and higher in summer. Sodium is hardly flushed by irrigation and leaching because it is retained by adsorption on mineral surfaces, especially by minerals having high cation exchange capacities, such as clay. There was no change in potassium concentrations, neither between summer and winter, nor between irrigated and non irrigated native soil. Calcium average concentrations were relatively higher for the native soil because of the cementing nature of calcium carbonate that can be partly flushed away due to irrigation. Soil was classified according to a combined classification of U.S. Salinity Laboratory (1954) and CSIRO (1989). Irrigated soils are mostly saline and strongly sodic, while native soils are mostly saline and non-sodic. Irrigated soil samples showed more sodicity during summer.

Conclusion

Salt affected soils impose a serious constraint to crop production on almost all cultivated land in Kuwait. Salinity problems are mainly due to inadequate water management. Most of the native soils in Kuwait are not saline, except in some coastal areas. The utilization of brackish groundwater in open field irrigation under high rates of evapotranspiration contributed over time to buildup of soil salinity and a high degree of sodicity. When comparing the salinity of native soils to soils in close proximity to irrigated soils, which have been exploited for the past 40 years since the establishment of Abdally farms, there was a clear increase in the soil salinity levels. Many of the farms mobilized large investments for the development of irrigation systems to enable local agriculture production to meet increasing food demands. Unfortunately, adequate irrigation management to control the buildup in soil salinity was not adopted. This caused soil degradation and increased salinization, in addition to the losses and inefficiency in water use. Groundwater has deteriorated since the expansion of agricultural activities in Abdally; moreover, controlled irrigation practices, which are commonly believed to be three times higher than what is required, resulted in the creation of serious hazards to the soil environment. It is recommended to use treated wastewater, which will allow the agricultural activities in Abdally area to have a wider range of crops to be grown. In addition, their yield will improve as salinity will be reduced. Such practices will also prevent the deterioration in both soil and groundwater resources.

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