J. Agric. Sci. Mansoura Univ., 32 (12): 10783 - 10797, 2007

DIFFERENTIAL SALT LOADING OF ON-SITE DRAINAGE WATER AND ASSOCIATED SALT BALANCE

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ABSTRACT

Monitoring of salt loading in soils and water is important to avoid salt accumulation and their subsequent degradation. A field experiment was implemented in two sites in the El-Zagazig County, each with workable subsurface drainage network. Maize and wheat were grown in sequence under conventional management procedures. Emitted drainage effluents in the manholes were sampled for volume and chemical determination. The results indicate that EC, SAR, and ion concentrations increased as a function of time, sometimes by a factor of 4, due to diminution of emitted water. In most cases, Na was the most dominantion due to feeble reactions with the exchange complex. Bivalent Ca, Mg, and SO_4 were closely affiliated to exchange, precipitation, and dissolution reactions. A considerable amount of salt was flushed out of the two fields during the growing season of maize followed by wheat. The total net salt balance of the two sites is negative, indicating that the soils have lost some of their initial salt content in an adventitious leaching process during irrigation. It is recommended that an integrated management of irrigation and subsurface drainage systems should be considered within a systemic approach to provide for the viable and sustainable agricultural production.

Keywords: salt balance, salinity, sodicity, subsurface drainage

INTRODUCTION

Irrigated agriculture is expanding rapidly worldwide on the expense of rainfed agriculture due to higher productivity and greater yield certainty (Rhoades et al., 1992; and Tahoun and El-Naka, 2002). With this accelerating momentum, many workers are well aware that irrigated agriculture carries some potential hazards. James et al. (1982) quoted several historians emphasizing that civilizations based on irrigated agriculture are doomed to fail. Several factors are submitted as most likely reasons, most important of which are inefficient irrigation water and accumulation of excess salts in the rhizosphere. Bresler et al. (1982) and Rhoades et al. (1992) estimated that approximately one third of the irrigated soils in the arid and semi-arid region of the world reflect some degree of salinity accumulation, and thus agricultural production decreases in proportion due to ensued soil degradation.

Irrigation with saline water is one of the main causes of secondary salinization resulting in eventual soil degradation. The effect of salinity is manifested in reduced plant growths, reduced yields quantitatively as well qualitatively, and total crop failure in severe cases (Rhoades and Loveday, 1990; Szabolcs, 1994; and Crescimanno and Garofalo, 2006). Leaching is considered the basic management tool for controlling salinity. Water is applied in excess of the total amount used by the crop and lost by evaporation.

It is conceded that some soil salinization is inevitable with irrigation, and that an amount ranging from 1 to 60 Mg of salt per hectare may be added to the irrigated soils annually (James et al., 1982). Thus, future expansion of food production should increasingly depend upon sound water management and upon concurrent maintenance of the present agricultural resource base. The binding principle here is that the soil possesses an adequate drainage system that allows the excess water to convey the hazardous salt load beyond the limit. In addition, the drainage system would also prevent water logging and the subsequent secondary salinization. It is of interest to note that Hoffman and van Genuchten (1983) emphasized that the concept of efficient water use must be expanded in regions of irrigated soils to accommodate the leaching requirement.

The salt load of drainage water was considered in a quantitative sense by the salt balance concept. As reported by Bresler et al. (1982) and Rhoades et al. (1992) the concept was developed by Schofield in the early forties of the last century on the premise that the quantity of salts in drainage water had to equal or exceed the quantity applied in irrigation water. Jury (1983) and Thellier et al. (1990) studied the salt movement and mass emission of salts out of irrigated soils. Their results indicated that the steady state model showed a more accurate salt balance calculation, and that many chemical reactions involved in the process such as the release of Ca ions from exchange sites and enhanced gypsum and $CaCO_3$ precipitation. The transient soil solution concentrations and salt precipitation rates in the root zone were influenced by ion composition and concentration of the applied water and soil exchange complex as well as by the infiltration rate.

Gardner (1983), Kelleners et al. (2000), and Gaynor et al. (2002) observed that soils differ in their ability to absorb, store, and transfer water, and these physical properties determine in part the suitability of many soils to sustain plant growth. It was given that as irrigation water is added to soils, it begins to infiltrate the surface in proportion to soil sorptivity. The drainage rate decreases rapidly down to a given water content, below which it becomes negligible. In conjunction, tile depth and spacing affect drainage volumes with greater drainage from tile at narrow spacing, and from deep rather than shallow depth. Furthermore, the leaching fraction has a considerable influence on the drainage water salinity. An increase in the leaching fraction from 0.2 to 0.4 reduced the time to reach equilibrium of drainage water salinity levels.

It should be pointed out, however, that increasing the leaching fraction would demand an increased supply of water, and this water may or may not be available. Moreover, many workers have begun to advocate the so-called integrated management of irrigation and subsurface drainage systems (Ayers and Westcot, 1994; Roman et al., 1999; Caballero et al., 2001; Wu et al., 2001; and Cao et al., 2004). The issues to be addressed include the sustainable alternatives for the management of water resources. In the circumstances, decisions are taken to minimize possible risks after undertaking an environmental impact assessment. More than often, improved irrigation scheduling/ efficiency could save irrigation water, but failed to provide adequate leaching of salts.

In this context, the salt balance concept was developed to monitor possible salt accumulation in soils as a function of time. The procedure requires measurements of water flowing into and out of the field, farm, and region depending on the scale of the investigation, similar to undertakings with nutrient balance (Scoones and Toulmin, 1998). Intensive work indicated that the most relevant variables of the salt balance include quantity and quality of the irrigation water as well as the initial salt load of the irrigated soil (Levy et al., 1983; James et al., 1982; El-Naka, 1993; Nabil, 1995; Dierfolf et al., 1997; Kelleners et al., 2000; and Wu et al., 2001).

The main objectives of this study are (i) to calculate the total salt balance of soil under different cropping systems; (ii) to monitor the impact of irrigation allotment given in fractions on the differential chemical composition of the individual ions so we can quantify the precipitated and/or dissolved soil minerals; and (iii) to audit the possible management practices in the irrigated areas.

MATERIALS AND METHODS

The experimental work was implemented on fields in the two villages of El-Ghar and El-Zankaloun, both located within 10 km diameter from El-Zagazig City, El-Sharkya Governorate. A detailed inventory was undertaken to choose sites that could each simulate a well-controlled system in the chemical sense as far as soil water inputs and outputs are concerned. Similar techniques were previously adopted by Ibrahim (1990), Bihery (2000), and Gaynor et al. (2002).

The experimental area in both cases was cultivated with maize followed by wheat. The El-Ghar field was managed by its owner whereas the El-Zankaloun field was managed by the local staff of the Drainage Research Institute. Preliminary analysis in Table 1 shows that the El-Ghar soil is clayey in texture with 49.6 % clay, non-saline with an EC_e value of 0.28 dSm^{-1}, and non-calcareous with 2.30 % $CaCO_3$. The El-Zankloun soil is heavy clayey in texture with 63.3 % clay, non-saline with an EC_e value of 0.35 dSm^{-1}, and non-calcareous with 3.60% $CaCO_3$.

The field management record shows that the irrigation water was given in cycles (6 cycles for maize and 4 cycles for wheat) to meet the crop water requirements was measured using a weir. Tile drains bisected each field site, and the drainage water was measured five or six times daily as it entered the drains manhole. Obtained water volumes were differentiated to calculate the sum of daily effluent emission in each case. Drainage water samples were collected for conventional chemical analyses comprising electrical conductivity (EC), pH, and soluble cations and anions according to methods given by Page et al. (1982).

RESULTS AND DISCUSSIONS

Before discussing the experimental results of this work, five points will be elaborated to serve as basic background materials. First, field observations have shown that emitted drainage water in almost all cases took at least 15 hours to reach the manholes of the two fields after delivering the irrigation water dose. Therefore, a lag time of one day was considered as standard commencing drainage cycles throughout this experiment.

Table1. Some charactersitics of EL-Ghar and EL-Zankalon soil.

Location	Clay%	silt %	sand %	CaCO3%	SP	EC dSm-1	Soluble Ions, mmol L-1 in soil sat. extract						
							Ca	Mg	Na	K	HCO3	Cl	SO4
EL-Ghar	49.60	27.90	22.50	2.30	77.00	0.28	37.66	8.57	61.04	4.16	67.53	25.97	17.92
EL-Zankalon	63.30	18.90	17.80	3.60	86.00	0.34	13.49	12.79	82.56	1.86	50.00	23.26	46.51

*: EC in saturation extract, SP: saturation percentage

Lag times as associated with water dynamics in soils were previously observed by irrigation engineers and soil physists. Jury (1983) utilized measured lag times to determine the infiltration rate of soils. But this particular soil character is out of context for the current research work.

Second, volume of emitted water decreased almost exponentially as a function of time to reach negligible values after 4 or 5 days, and vanished beyond 7 days after irrigation delivery. Therefore, it was decided during the preparation of this text not to report volumes of less than 3 cubic meters per faddan per day in both Tables 2 and 3, otherwise the tables would look bulky and too cumbersome for printing. However, implicated impact of the actual volume on the associated salt balance was incorporated in the calculation of the salt and elemental balances. Thellier et al. (1990) and Gaynor et al. (2002) observed that the depth and spacing of drains affect drainage volumes, and that the greatest drainage volume came from tile at narrow spacing, and from deep rather than shallow depth.

Third, regarding volumes of irrigation doses and drainage emissions, several features should be outlined for those who may be concerned. (1) Maize received much more irrigation water compared to wheat, indicating different water requirements. (2) Duration of drainage emissions lasted much longer with wheat compared to maize, implying different evapotranspiration rates. (3) Sum of drainage effluents represents a considerable portion of the applied irrigation water. The phenomenon is complicated with a multiplicity of variables including soil, water, crop, and climatic conditions (Dierfolf et al., 1997; Roman et al., 1999; Caballero et al., 2001; and Endale et al., 2006). The implication of this result on the overall water use efficiency deserves some elaborations both on the technical and economical perspectives.

Fourth, volumes of individual irrigation doses given to the fields were based on the traditional knowledge of farmers in the area. The author only calibrated it using a weir. It is of interest to note that the El-Ghar field whose soil contains 49.6 % clay received less irrigation water compared to the El-Zankaloun field whose soil contains 63.3 % clay. However, the sums of entire emitted drainage effluents from the two fields throughout the two cultivated crops are comparable at 1271 cubic meters for El-Ghar and 1286 for El-Zankaloun. It is admitted that the available equipment to measure these volumes were not rigorous and sophisticated as desired, and therefore, the obtained figures for water volumes in this work are considered only indicative, waiting for refined equipment to obtain refined relevant results.

Fifth, no traces of CO_3 were ever found in the effluent emissions of both fields and the two crops. Actually, this is an expected result given the high quality of the soils and the irrigation water in the area.

Diurnal changes in pH, salinity, and sodicity

Tables 2 and 3 show the experimental values of the drainage water emitted from the two cultivated fields of this work. It is self-evident that values vary depending on spatial, temporal, site specifics, and crop characteristics.

Table 2. Chemical composition of irrigation and effluent drainage waters from El-Ghar field

irrigation cycle	irrigation, m3 / faddan	days	drainage, m3/ faddan	pH	EC, dS/m	concentration of ions, mmole/ L (charge)							SAR
						Ca	Mg	Na	K	HCO3	Cl	SO4	
Maize													
planting	450	1	188.1	6.82	1.22	1.84	1.56	9.41	0.28	5.52	3.60	5.28	7.22
		2	65.0	7.00	1.33	1.96	1.73	10.74	0.26	5.64	4.00	7.06	7.91
		3	6.6	7.42	1.79	2.29	1.94	14.31	0.28	5.38	4.88	9.34	9.84
1st	390	1	111.6	7.10	1.11	1.22	2.07	8.47	0.32	6.76	2.60	4.27	6.60
		2	72.8	7.22	1.20	1.32	2.15	9.24	0.24	7.28	2.30	4.49	7.01
		3	5.9	7.12	1.32	1.73	2.31	10.04	0.24	8.68	3.00	4.58	7.06
		4	3.2	7.10	1.46	1.84	2.95	10.90	0.23	9.48	3.40	5.11	7.04
2nd	405	1	155.5	7.10	1.19	0.71	2.59	8.39	0.22	7.16	2.40	2.42	6.53
		2	52.4	7.54	1.24	1.12	2.67	8.46	0.22	8.04	2.88	1.66	6.14
		3	6.1	7.42	1.61	1.73	2.83	10.81	0.24	9.16	3.40	2.25	7.16
3rd	414	1	125.6	7.44	0.93	1.22	2.55	6.32	0.20	6.10	1.60	3.51	4.60
		2	65.2	7.64	1.02	1.12	1.80	7.46	0.16	7.00	1.60	2.56	6.18
		3	8.3	7.34	1.49	1.73	3.06	10.40	0.18	7.63	1.80	6.32	6.72
		4	4.1	7.30	2.20	2.04	4.46	14.60	0.22	9.28	4.60	6.71	8.10
4th	417	1	110.4	7.93	1.43	2.95	3.92	10.13	0.38	7.92	2.20	8.48	5.46
		2	54.8	7.98	1.61	3.26	4.93	11.59	0.36	8.04	2.80	10.39	5.73
		3	14.5	8.03	1.65	3.46	5.01	11.78	0.34	8.84	3.28	10.01	5.73
		4	5.2	7.95	2.03	3.57	5.01	7.14	0.32	9.76	4.08	5.53	3.45
		5	3.4	8.03	2.31	3.77	5.36	16.31	0.24	10.08	8.40	9.71	7.63
5th	411	1	108.6	7.01	1.10	2.24	3.40	6.55	0.14	9.64	1.60	2.34	3.90
		2	52.3	7.03	1.23	2.65	3.09	7.55	0.04	10.36	1.80	2.32	4.46
		3	10.7	7.26	1.36	2.85	3.74	8.42	0.06	11.12	1.80	3.53	4.64
		4	6.0	7.30	1.97	2.75	5.44	13.11	0.06	11.68	4.00	7.17	6.48
		5	3.4	7.31	2.12	3.36	5.11	14.04	0.10	11.60	4.80	7.50	6.82

Table 2. cont.

irrigation cycle	irrigation, m3 / faddan	days	drainage, m3/ faddan	pH	EC, dS/m	concentration of ions, mmole/ L (charge)							SAR
						Ca	Mg	Na	K	HCO3	Cl	SO4	
						Wheat							
planting	285	1	66.6	6.90	2.54	4.91	4.53	17.04	0.18	9.40	9.00	9.41	7.84
		2	53.5	7.00	3.12	5.20	4.75	22.42	0.24	9.70	10.00	14.22	10.05
		3	23.9	7.02	3.48	5.78	5.45	24.97	0.18	10.05	12.00	15.81	10.54
		4	17.6	7.21	3.51	6.07	5.67	24.99	0.20	10.60	12.40	15.62	10.31
		5	3.7	7.25	3.54	6.36	5.58	25.97	0.22	11.10	12.90	16.79	10.63
1st	255	1	72.4	6.92	2.28	4.62	4.31	14.92	0.16	8.90	9.00	7.28	7.06
		2	58.5	7.02	2.78	5.78	3.91	19.32	0.18	11.20	10.00	9.59	8.78
		3	30.1	7.20	3.19	6.07	5.16	22.16	0.20	12.40	11.00	11.96	9.35
		4	25.4	7.22	3.21	6.36	5.02	22.47	0.20	12.45	11.20	12.42	9.42
		5	8.9	7.23	3.25	6.65	5.19	23.07	0.22	12.55	12.00	13.30	9.48
2nd	258	1	60.7	6.91	0.81	3.60	2.23	4.16	0.32	5.90	6.50	0.16	2.44
		2	47.8	7.12	1.40	5.49	2.89	8.33	0.32	8.40	7.00	3.97	4.07
		3	29.8	7.25	2.28	5.78	3.22	14.78	0.34	11.40	7.60	6.48	6.97
		4	18.1	7.20	2.40	6.36	3.33	15.65	0.34	11.40	8.00	7.85	7.11
		5	14.8	7.10	2.63	6.94	4.29	17.37	0.34	11.50	10.00	9.70	7.33
		6	4.1	7.04	2.98	7.05	4.79	19.90	0.34	11.75	12.00	10.50	8.18
3rd	252	1	51.4	6.81	1.36	1.73	2.61	10.20	0.32	8.20	7.20	2.38	6.93
		2	39.7	6.99	1.84	2.60	3.44	12.87	0.32	9.30	8.90	2.57	7.41
		3	33.5	7.02	2.39	4.97	3.74	15.27	0.34	9.90	9.60	5.30	7.32
		4	10.6	7.23	2.63	6.13	4.69	16.50	0.34	10.50	11.00	7.43	7.10
irrigation water analysis				6.93	0.44	1.96	1.16	3.62	0.29	3.65	0.83	2.55	2.89

Table 3. Chemical composition of irrigation and effluent drainage waters from El-Zankaloun

irrigation cycle	irrigation, m3 / faddan	days	drainage, m3 / faddan	pH	EC, dS/m	concentration of ions, mmole/ L (charge)							SAR
						Ca	Mg	Na	K	HCO3	Cl	SO4	
						Maize							
planting	605	1	252.9	7.22	1.44	5.14	4.69	7.95	0.08	6.18	5.52	6.78	3.58
		2	87.4	7.32	2.65	8.28	8.52	15.95	0.08	7.12	14.82	12.78	5.50
		3	8.9	7.40	3.65	9.29	12.40	21.55	0.09	8.15	21.32	16.27	6.54
		4	5.2	7.52	4.71	9.99	13.20	27.54	0.10	9.14	22.40	20.62	8.09
1st	417	1	119.4	7.14	1.82	4.88	3.88	11.40	0.06	7.19	4.88	8.90	5.45
		2	77.8	7.28	2.82	7.82	9.89	17.83	0.08	8.05	15.28	14.60	5.99
		3	6.4	7.34	3.84	9.14	12.30	23.07	0.09	9.18	18.44	18.73	7.05
2nd	558	1	214.2	7.48	1.58	4.69	3.69	9.80	0.80	7.88	4.80	7.04	4.79
		2	72.2	7.55	3.65	9.99	9.61	22.37	0.10	11.28	15.80	17.08	7.15
		3	8.4	7.65	4.00	9.89	13.76	23.67	0.08	10.60	17.20	20.87	6.88
3rd	303	1	91.9	7.12	1.92	5.50	4.48	9.57	0.08	8.70	5.36	5.74	4.28
		2	47.7	7.26	3.83	8.26	20.11	17.73	0.06	11.40	14.20	19.78	4.71
		3	6.1	7.30	5.33	10.50	16.83	29.13	0.06	11.36	23.36	22.66	7.88
		4	3.0	7.45	5.40	9.28	10.32	34.02	0.08	10.48	24.80	18.18	10.87
4th	239	1	63.2	7.10	2.99	5.37	8.44	17.34	0.10	11.04	10.20	10.72	6.60
		2	31.4	7.21	4.71	8.96	14.79	24.58	0.08	12.00	20.20	16.66	7.13
		3	8.3	7.34	5.05	11.31	14.87	26.93	0.08	11.30	22.60	19.62	7.44
		4	3.0	7.36	5.08	9.96	19.43	25.63	0.08	11.60	23.00	21.24	6.69
5th	340	1	89.9	7.25	2.65	5.60	7.66	14.13	0.04	6.76	9.20	11.66	5.49
		2	43.2	7.36	4.62	10.08	13.78	23.61	0.06	9.08	19.40	19.30	6.84
		3	8.9	7.37	4.86	10.41	15.54	24.75	0.06	8.88	21.80	20.47	6.87
		4	5.0	7.59	4.93	10.41	15.76	24.78	0.06	8.56	21.80	20.91	6.85

Table 3. Cont.

irrigation cycle	irrigation, m3 / faddan	days	drainage, m3 / faddan	pH	EC, dS/m	concentration of ions, mmole/ L (charge)							SAR
						Ca	Mg	Na	K	HCO3	Cl	SO4	
						Wheat							
planting	417	1	97.6	6.90	0.85	2.88	2.21	4.62	0.12	6.50	1.40	2.61	2.90
		2	78.4	7.20	0.98	3.98	3.42	4.87	0.11	7.22	2.40	3.49	2.53
		3	35.0	7.34	1.98	4.86	3.89	11.18	0.07	9.14	3.50	7.45	5.35
		4	25.9	7.52	2.54	7.88	5.66	11.28	7.00	10.44	5.50	9.68	4.34
		5	5.4	7.98	2.55	9.54	7.52	14.45	0.08	11.55	7.50	13.25	4.95
1st	300	1	85.5	6.96	0.75	3.18	2.43	4.12	0.14	6.05	1.50	3.06	2.46
		2	69.1	7.00	0.95	4.05	4.11	4.67	0.10	7.20	2.50	3.83	2.31
		3	35.5	7.50	1.35	4.62	4.82	7.74	0.08	8.40	3.50	6.30	3.56
		4	30.0	7.22	1.93	8.38	5.62	10.72	0.08	11.00	5.00	9.55	4.05
		5	10.5	7.25	2.37	9.83	7.52	13.48	0.08	11.50	7.00	12.86	4.58
		6	3.6	7.40	2.40	10.23	9.06	13.87	0.08	11.65	7.50	13.98	4.46
2nd	288	1	68.1	7.10	1.92	6.07	7.45	10.29	0.34	9.70	8.00	7.82	3.96
		2	53.7	7.06	3.40	10.69	12.27	18.03	0.50	11.30	16.00	15.42	5.32
		3	33.4	7.12	4.67	15.32	17.59	24.15	0.24	12.40	25.00	21.26	5.95
		4	20.3	7.22	5.73	20.23	21.36	29.56	0.18	12.40	32.50	27.48	6.48
		5	16.6	7.23	6.16	21.68	21.95	31.26	0.53	12.30	36.00	28.42	6.69
		6	4.6	7.45	6.24	21.76	23.31	31.44	0.24	12.50	36.20	29.12	6.62
3rd	312	1	63.6	7.01	0.85	5.89	3.70	5.20	0.32	6.60	7.50	3.80	2.37
		2	49.1	7.21	2.25	8.96	10.68	12.70	0.44	9.25	15.50	10.42	4.05
		3	41.5	7.13	3.85	13.01	16.99	20.53	0.20	11.05	24.50	17.35	5.30
		4	13.1	7.23	4.44	18.56	21.49	22.00	0.18	12.20	31.20	20.23	4.92
		5	3.8	7.34	5.85	22.25	19.64	30.14	0.44	12.30	32.50	28.49	6.59
irrigation water analysis				7.22	0.35	1.87	1.32	4.75	0.25	3.47	1.00	3.27	3.76

Although the pH values do not undergo dramatic changes, there is a steady and consistent increase in pH within drainage cycles in both experimental locations and the two crops. This trend is closely associated with a similar increase in emitted water salinity, but more logically associated with an increase in the HCO_3 concentration.

The EC values progressively increase as the drainage cycle proceeds. This is most likely due to insufficient water to dilute the effluent. It is noted that the values of the first drainage installment is invariably lower than that of the last in the preceding cycle. Therefore, the on-going leaching process produces drainage water whose salinity concentration approximates a semi-sinusoidal function. Values coming out of El-Ghar soil were mostly lower then that of El-Zankaloun, and the difference between the first and the final emission was also smaller. The last noticeable trend is that the highest EC value of the drainage water is associated with wheat rather than maize, and that the high values are temporally associated with mid season rather than the beginning or the end. A possible explanation is that the physiological crop activity at the time was too high to leave minimal amount water for leaching. The emitted volumes of drainage water in Tables 2 and 3 substantiate this argument.

The sodium adsorption ratio (SAR) as an indicator to sodicity (James et al., 1982) of the effluent drainage water is shown in Tables 2 and 3. It is evident that the SAR values are somewhat associated with salinity, showing the same trend. In the El-Ghar field, with both maize and wheat as the growing crops, the SAR values were higher early in the season, and then tended to decrease towards the end of the season. The case was not identical in the El-Zankaloun field. Furthermore, increases in the SAR values of the El-Zankaloun effluents were a bit subtle as a function of both time of the season and time in the cycle.

Diurnal changes in ion concentrations

Potassium may be singled out from the ions pool of both Tables 2 and 3 with two distinctive characteristics. First, its concentration is much smaller than any other cation. Second, its concentration does not undergo considerable changes during the successive drainage cycles of the two field plots. Such behavior is typical of the classical soil K behavior, where soils with high clay content exert pronounced buffering capacity to establish and maintain equilibrium between different K forms (Sparks, 1995).

Calcium concentration of effluents coming from El-Ghar field is invariably lower than that coming from the El-Zankaloun field, indicating some intrinsic properties of individual soils. However, drainage effluents emitted from both fields showed remarkable concentration increase towards the end of each emission cycle, sometimes by a factor of 4.

It can be also noted that the Ca concentration in the effluent increases by great proportion in the El-Ghar field going from maize to wheat. Whether such trend is associated with a change in plant canopy from maize to wheat, or a change in climatic condition from summer to winter is a question to be answered by some future investigations. The trend of concentration increase from maize to wheat was not very obvious in the El-Zankaloun field.

Nevertheless, the highest Ca concentration at 22.25 mmole$_c$ L^{-1} is recorded when the wheat cultivated in this field.

Magnesium concentration in the effluent emissions follows the same trends of Ca, with some exceptions. On the similar side, effluents coming from El-Ghar field is invariably lower in Mg than that coming from the El-Zankaloun field, and that the concentration increases at the end of the emission cycle. The exception is that changing the type of plantation in the two fields does not necessarily produce the same effect on Mg concentration.

In most cases, Na is the most dominant cation in the drainage effluents. This explains, at least in part, the fairly high SAR values of effluents compared to the utilize irrigation water. This high concentration could be interpreted by the results obtained by El-Naka (1999). He found that Na ions were the most easily removable ions during leaching salt-affected soils due to feeble reactions with the exchange complex. Bivalent Ca, Mg, and SO_4 were closely affiliated in their movement and that was attributed to the fact that these ions are susceptible to exchange, precipitation, and dissolution reactions.

The concentration of HCO_3 does not show great variations; especially if the two soils are set for comparison. This is probably due to the fact that it is mostly controlled by the partial CO_2 pressure of the ambient atmosphere as reported by Sparks (1995). Chloride and sulphate concentrations in the El-Ghar field are much less than those of the El-Zankaloun. Several variables may be involved in the process. Most important are the intrinsic soil properties in each field and the exact quantity and qualities of utilized irrigation water. In this context, Annandale et al. (1999) and Kelleners et al. (2000) found that an increased leaching fraction has a considerable influence on the drainage water salinity, as it will reduce the time to reach equilibrium of drainage water salinity levels.

Net Salt Balance

The calculated net salt balance of the two fields over the entire growing season is obtained by summing up the product of salt concentrations times the volume of individual drainage emission. Data in tables 2 and 3 were used to calculate the total salt balance by the following equation according to **Wilcox and Resch (1963):**

$$SB = \sum_{i=1}^{I} CdwVdw - \sum_{i=1}^{I} CiwViw$$

Where SB is net of total salt removed or acquired, kg faddan^{-1}, $C_{dw}V_{dw}$ is the diurnal concentration and volume of the emitted drainage water, $C_{iw}v_{iw}$ is the concentration and volume of irrigation water applied for every irrigation cycle, Σ is the sum sign, and i is the number of drainage/irrigation cycle (i =1,2,3,......I). A positive salt balance denotes that this field removed salts to the effluent drainage water.

It should be pointed out the level of certainty regarding chemical analysis to determine salinity is very high to approach perfection. However, volumes of emitted water were obtained using reiterated periodical measurements of water and then extrapolating over time. In the circumstances, the level of certainty is not high, but there was no other way to implement this work. Given these considerations, discussion of the total salt balance data should be directed towards general trends rather than exact specifics.

The data in Table 4 indicate that the El-Ghar field shows a positive salt balance of 1041.4 kg salt per faddan after growing maize followed by wheat, meaning that more than one Mg of salt was flushed out of the field. The corresponding figure for the El-Zankaloun field is 2196.6 kg per faddan. It is most likely that a considerable portion of this difference could be interpreted within the intricate frame comprising quantity and quality of irrigation water, consumptive water use of cultivated crops and the associated evapotranspiration rates, and the intrinsic soil properties.

In this context, Ayers and Prescot (1994), Roman et al. (1999), Wu et al. (2001), and Caballero et al. (2001) emphasized that improved irrigation efficiency would certainly save much of the irrigation water and reduce drainage water. However, improving irrigation may reduce deep percolation and thus fail to provide adequate leaching of salts. Therefore, an integrated management of irrigation and subsurface drainage systems should be considered within a systemic approach to provide for the viable and sustainable agricultural production.

Table 4. The salt balance, Kg faddan^{-1}of tow seasons for El-Ghar and El-Zankaloun soil.

Crop	Drainage/Irrigation			total salt balance, kg faddan^{-1}			
	cycle						
		$C_{dw}V_{dw}$	$C_{iw}V_{iw}$	SB	$C_{dw}V_{dw}$	$C_{iw}V_{iw}$	SB
			El-Ghar			EL-Zankalon	
Maize	planting	210.40	126.70		417.70	135.50	
	1st	145.60	109.80		295.10	93.40	
	2nd	166.30	114.00		406.50	125.00	
	3rd	131.00	116.60		261.00	67.90	
	4th	184.10	117.40		252.00	53.50	
	5th	139.00	115.70		323.70	76.20	
	SUM	976.40	700.20	276.20	1956.00	551.50	1404.5
Wheat	planting	320.90	80.30		197.50	93.40	
	1st	401.40	71.80		172.20	67.20	
	2nd	178.30	72.70		458.50	64.50	
	3rd	160.40	71.00		258.90	69.90	
	SUM	1061.00	295.80	765.20	1087.10	295.00	792.1
	TSB			1041.40			2196.6

$C_{dw}V_{dw}$ is the diurnal concentration and volume of the emitted drainage water for drainage cycle

$C_{iw}V_{iw}$ is the concentration and volume of irrigation water applied for every irrigation cycle

SB is net of total salt removed or acquired, kg faddan-1

SUM is the summation sign

TSB is total salt balance for the two seasons, kg faddan-1

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J. Agric. Sci. Mansoura Univ., 32 (12), December, 2007

التباين النسبي في حمولة مياه المصرف من الاملاح و حسابات الميزان الملحي

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تهدف هذه الدراسة بصفة رئيسية الي حساب الميزان الملحي الكلي للارض تحت انظمة محصولية مختلفة ومتابعة التغيرات المستمرة في تركيزالايونات لمياه الصرف المتدفقة و بالتالي يمكن توقع الكميات المترسبة و الذائبة لمعادن التربة و كذلك تحديد عمليات الخدمة الممكنة في المناطق المروية بطريقة دقيقة.

اجريت تجربة حقليه في موقعين بالقرب من مدينة الزقازيق (الغار والزنكلون) حيث يعمل بهما شبكة صرف مغطي. تم زراعة الذرة والقمح فيهما تحت ظروف طرق الخدمة التقليدية ثم اخذت عينات من مياة الصرف المتدفقة الي المصارف الرئيسية بصفة مستمرة و تقديرها كميا و كيميائيا.

تشير النتائج الى ان مياه الصرف المتدفقة الى المصارف استغرقت حوالى ١٥ ساعة على الاقل لكي تصل الى الفتحات الرئيسية التى يتم فيها تجميع المياه وذلك فى كلا الحقلين بعد اعطاء الارض جرعة من مياه الرى. كما اظهرت النتائج ان حجم المياه المنصرفة الى المصارف تتناقص بشكل أسى مع الزمن الى ان تصل فى النهاية الى قيم صغيرة بعد حوالي ٤ او ٥ ايام ثم تتلاشى تماما بعد مرور ٧ ايام من عملية الرى وان نبات الذرة كان الاكثر استهلاكا للمياه مقارنة بنبات القمح و ان مياه الصرف استمرت وقت اطول مع القمح مقارنة بالذرة.

تشير النتائج الي ان قيم التوصيل الكهربائي لمياه الصرف تزداد مع تقدم زمن الصرف وذلك لتناقص كمية المياه المنصرفه ، وان اعلى قيم لوحظت مع نبات القمح مقارنة بنبات الذرة وذلك كان اكثر وضوحا فى منتصف موسم النمو. كما تظهر النتائج ان قيم ال SAR لمياه الصرف كانت الاعلى فى منطقة الغار فى المراحل الاولى من النمو ثم تقل مع نهاية الموسم.

تظهر النتائج ان تركيز ايونات الكالسيوم فى مياه الصرف فى منطقة الغار كانت قليلة مقارنة بالزنكلون ولكن كانت هناك زيادة تصل الي ٤ اضعاف مع نهاية دورة الصرف ، وان اعلى تركيز للكالسيوم وصل الي ٢٢,٢٥ مليمول/لتر لوحظ مع نبات القمح فى منطقة الزنكلون. اما ايونات الماغنسيوم كانت تاخذ نفس اتجاهات الكالسيوم تقريبا. بالنسبة لايونات الصوديوم فكانت هى السائدة فى مياه الصرف وكانت السبب فى ارتفاع قيم ال SAR. بالنسبة لايونات البيكربونات لم تظهر اختلافات كبيرة فى كلا الموقعين ، اما ايونات الكلوريدات و الكبريتات فكانت اقل بكثير فى منطقة الغار عنه فى منطقة الزنكلون.

تشير النتائج الي ان الميزان الملحى فى كلا الموقعين اعطى قيما موجبة مما يدل على ان هناك فقد فى الاملاح فى هذه الاراضى الي مياه الصرف ، حيث كانت القيم فى منطقة الزنكلون اعلى حوالى الضعفين تقريبا مقارنة بمنطقة الغار ، حيث وصل الميزان الملحى فى ارض الغار الى ١٠٤٠ كجم/فدان بينما فى منطقة الزنكلون وصل الى ٢١٩٦ كجم/فدان وذلك خلال موسمى النمو وهذا ربما يرجع الى الاختلاف فى كمية و نوعية مياه الرى المستخدمة فى كلتا المنطقتين واختلاف الاستهلاك المائى للمحاصيل المنزرعة ومعدلات البخرنتح وخواص التربه وكذلك طرق الخدمة المتبعة ونظام استخدام الاسمدة.

من هنا تعتبر مراقبة حمولة الاراضي و المياه من الاملاح من الامور الهامه لتلاشي حدوث تراكم للاملاح بها و بالتالي التقليل من تدهورها ، لذا نوصي باتباع طرق خدمة متكاملة لعمليات الري و كذلك انظمة الصرف المغطي من خلال طرق نظامية لضمان انتاج زراعي قابل للحياة و مستدام .