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THE MAGNITUDE OF EVAPORATION LOSSES IN INCREASING SALINITY OF DRAINAGE WATER

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Abstract

The severe and increasing shortage of water resources in Egypt becomes imperative to consider re-use of drainage water, which salinity in the drainage water is often difficult to quantify with confidence.

A preliminary study has been carried out to estimate the evaporation losses in the rice field, as well as, the effect of this loss on increasing salt concentration of the residual water, where the proportion of water lost to the atmosphere by evaporation rather than transpiration should be greater for this crop than for any other major crop in the Delta.

For this study, water samples were collected during June 1988 from El-Roda (conventional drainage system) and Nashart (modified drainage system) rice fields and analyzed for a stable isotope and some major elements.

The main finding is that the extent of heavy stable isotope enrichment in the rice field samples due to evaporation is quite large. From this we can estimate the amount of water lost by evaporation and determine the increasing in salt concentration due to loss in water. This finding can be quite helpful in establishing the sources of salts in the drainage water.

INTRODUCTION

Expanded re-use of drainage water for irrigation is a central component of future agricultural planning for Egypt, where there is urgent need to enhance utilization of available resources of water.

During 1988 the total discharge of drainage water for the whole Nile Delta was 14,350 million m3, from which there is about 2,379 million m3 has been reused for irrigation. Theoretically, there are about 1.1 billion m3 of drainage water in the salinity class up to 1000 g/m3 and about 2.1 billion m3 in the salinity class 1000-1500 g/m3 available for re-use in the irrigation system (1). Thus, it is esential to have an accurate estimate of drainage flows and salinity as well as the sources of dissolved salts in the drainage network.

Since the isotopic composition of water is not altered by dissolution or precipitation of soluble salts, the isotopic composition of drainage water allows the calculation of the salinity budget independently of the water budget.

At present, the flux of salt from the drainage network appears considerably greater than the annual input delivered by the irrigation water. If this extra salt is derived from leaching of the soil soluble salts accumulated over long period of relatively inefficient soil flushing in the past, rather than evaporation of recent irrigation water, eventually this "extra" salt burdens in the drainage area will decline, resulting in improved drainage water quality.

This research have been carried out to detect the relation between evaporation and increasing deuterium concentration in the rice field drainage water, to follow the reason and sources of salts in the drains.

MATERIALS AND METHODS

Two pilot areas (Roda and Nashart) have been selected in the Middle Delta in cultivated rice areas, approximately three quarters of the way from Cairo to the

Mediterranean Sea (Fig. 1). Drainage in the Roda area is accomplished by tile drains distributed in a lay-out typical for most of the delta. In contrast, the drainage geometry in the Nashart area permits conservative water management during rice cultivation to substantially reduce drainage losses (modified drainage lay-out for rice areas). Twenty four samples have been collected during summer season, 1988; from both areas, 8 samples from flooded rice fields (5 samples from El-Roda area and 3 samples from Nashart), 14 drainage samples (6 samples from the drains in El-Roda one of them from cotton field) and 8 samples from the drains in Nashart 2 of them from maize field), and two irrigation water samples (Fig. 2 illustrates the drainage lay-out in both areas and the sample locations).

Evaporation pan experiment was carried out at the same time where evaporation pan of 125 cm diameter was filled to a depth of 20 cm with Nile water. The pan was located in Sakha, Kafr El-Sheikh Governorate in the middle of the Nile Delta. The water in the evaporation pan was sequentially sampled over a period of one month till depth decreased to 2 cm.

The collected samples were analyzed for the following:

Total soluble salts and pH; together with anion and cation concentration (according to Jakson, 1967).

Deuterium and oxygen 18 were analyzed at the Middle Eastern Regional Radio Isotope Center in Cairo where they are measured mass spectrometrically. Deuterium was produced from water samples by reduction with heated zinc under vacuum (Coleman *et al.* 1982), whereas oxygen-18 was measured in the form of carbon dioxide after equilibrating with water samples in special sample preparation line (Epstein and Mayeda 1953). The isotopic compositions are expressed as per mil deviation (%O) of the ratio D/H or O^{18} / O^{16} against SMOW (Standard Mean Ocean Water).

RESULTS AND DISCUSSION

Due to the reduced supply of irrigation water available in the late June of 1988; there was considerable re-use of drainage water in some zones of both the

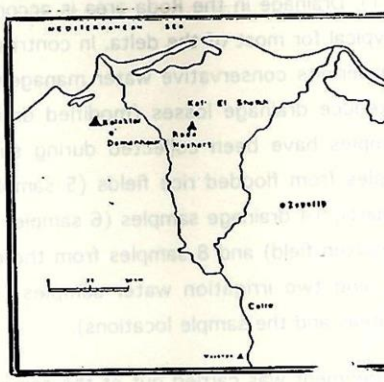
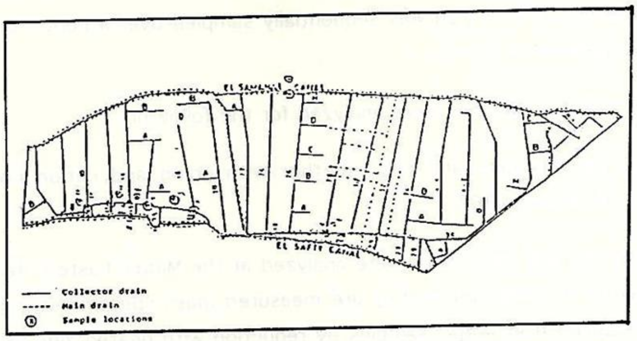
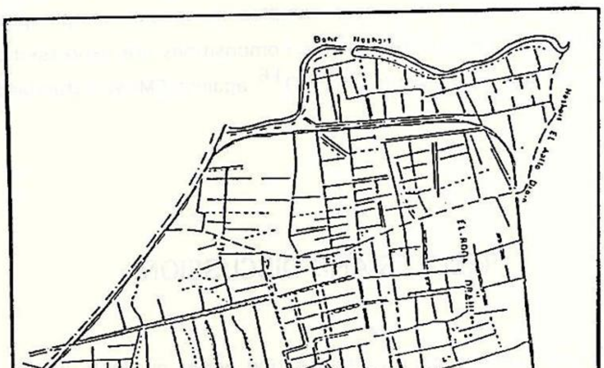


Fig. 1. Location of Experimental Field



Layout of El-Roda (Conventional system)



Layout of Nashart (Modified system)

Fig. 2. Layout and Sample Locations of El-Roda and Nashart.

Roda and Nashart areas (one of the irrigation water samples has salinity of 218 ppm, while the other was 339 ppm with about 50% greater than the first one and clearly had an appreciable component of drainage water).

The total dissolved salts (TDS) of the drainage samples averaged about 2000 ppm and the samples from flooded rice fields averaged about 1400 ppm (Table 1).

Samples from the both drains and rice fields in the Roda area averaged somewhat higher in salinity than those from Nashart. Roda drains averaged 2270 ppm TDS while the Nashart drains averaged about 1850 ppm and were considerably less saline (about 1500 ppm). This may be due to the higher irrigation water requirements in Roda (conventional drainage system) which lead to the use of drainage water in irrigation and this caused salt input.

The major new finding from the stable isotope measurements was that the rice fields had much higher deuterium to hydrogen ratio (average delta D = +49%O) than irrigation waters (delta D = +30%O). In contrast the drainage waters did not have the extreme heavy isotope enrichments displayed by the rice fields.

The results from the evaporation pan experiment are illustrated in Fig. 3 where D of water remaining in the pan is plotted against the fraction of water evaporated from the pan. If we consider the linear part of the relation, it could be concluded that each 1% loss to evaporation resulted in an increase of D by about 0.643%O.

Using this relation between deuterium enrichment and fraction of evaporation losses we could estimate the average fraction of evaporation losses in the rice fields. The results obtained from the rice fields indicate that the deuterium enrichment was equal to 19%O (the differences between D in rice field and D in irrigation water) which means that the average fraction of evaporation losses is 30%, about five times that derived from the drainage water (where it was 6% in the drainage water) (Table 2). Thus the rice field water were much more enriched in deuterium and somewhat less saline than drainage water from the same collector network.

The substantial difference of deuterium concentrations in the rice fields compared with drains can be detected clearly as shown in Fig. 4, which shows little overlap in the range of observed values. In contrast, the salinity levels of these two types of samples both had similar ranges of values. From the same figure, it could be noticed that the all samples from the flooded rice field are nearly much higher in

Table 1. Concentration of total dissolved salts, chloride, Delta deuterium and silicon concentration in different samples.

Sample Code	Sample	TDS	Cl (g/l)	Delta (D(0%)	Si (mM)
RN-01	18[3]-Ir.Rice	0.220	0.041	28.200	0.070
RN-08	16-Ir.Rice	0.340	0.047	32.200	0.237
R[1]-02	28-Dr.Rice	1.750	0.320	31.800	0.375
R-04	18-Dr.VMC	2.400	0.490	32.100	0.465
R-06	16-Dr.Rice	2.590	0.570	36.100	0.432
R-09	14-Dr.Rice	1.820	0.270	34.300	0.515
R-11	12-Dr.Cot.	2.840	0.560	34.500	0.425
R-12	10-Dr.Rice	2.190	0.460	39.900	0.417
N[2]-14	08-Dr.Rice	1.500	0.290	37.700	0.342
N-16	06-Dr.R,C.	1.700	0.350	40.300	0.344
N-17	04-Dr.Maiz	4.610	1.230	27.900	0.542
N-18	09-Dr.Rice	1.360	0.330	31.600	0.252
N-20	15-Dr.Rice	1.250	0.240	36.000	0.252
N-22	17-Dr.Maiz	1.550	0.310	30.200	0.283
N-23	19-Dr.Maiz	1.250	0.230	32.100	0.281
N-24	21-Dr.Rice	1.590	0.360	31.400	0.261
R-03	28-Fd.Rice	1.720	0.390	40.300	0.180
R-05	16-Fd.Rice	1.970	0.490	48.000	0.064
R-07	16-Fd.Rice	0.810	0.100	58.300	0.018
R-10	14-Fd.Rice	7.000		56.600	0.145
R-13	10-Fd.Rice	1.560	0.360	45.800	0.081
R-15	08-Fd.Rice	1.260	0.200	47.600	0.134
R-19	09-Fd.Rice	1.800	0.470	53.000	0.096
R-21	15-Fd.Rice	0.520	0.080	47.300	0.206

1. Samples from El-Roda area
2. Samples from Nashart area
3. No. of field drain from which the sample has been taken.

Table 2. Summary of salinity and stable isotope data from rice field.

Location	Property	Irrigation	Drain	Rice Field
Roda	TDS (g/l)	0.28+0.08	2.27+0.43	(1.52+0.50)a
Roda	Cl (g/l)	0.044+0.004	0.45+0.12	(0.34+0.17)a
Roda	Delta D%0	+30.2+2.8	+34.8+3.0	(+49.8+7.5)a
Nashart	TDS (g/l)	--	1.85+1.13	1.19+0.64
Nashart	Cl (g/l)	--	0.42+0.33	0.25+0.20
Nashart	Delta D%0	--	33.0+4.0	+49.3+3.2
Roda + Nashart	TDS (g/l)	0.28+0.08	2.03+0.89	1.38+0.54
Roda + Nashart	Cl (g/l)	0.044+0.004	0.43+0.26	0.30+0.17
Roda + Nashart	Delta D%0	+30.2+2.8	+33.8+3.6	+48.6+5.7
Roda + Nashart		--	+3.6	+18.4
Fraction lost to evaporation -b			6%	28%

deuterium values than the drainage samples which mean that the evaporation losses from flooded rice fields are much higher than from drainage surfaces. There is no simple relationship between deuterium and TDS. Fig. 5 illustrates the relation between Cl and electrical conductivity. It could be observed from this relation that the main source of salinity in these water samples is the presence of Na Cl salts.

The amount of HCO3 in solution in the rice fields seems to have an upper bound of about 10 meq/l (Fig. 6), with the rice samples generally lower than the drains. This is consistent with greater likelihood of calcium carbonate precipitation in the rice field water due to lowered partial pressures of carbon dioxide by exchange of gases with the atmosphere.

The silicate concentrations of drainage water averaged much higher than irrigation water for both Roda (0.44 mM) and Nashart (0.32 mM), while the rice fields in the two areas had much less salinity contribution from silicate mineral weathering; Roda 0.10 mM and Nashart 0.15 mM. These differences are illustrated in Fig. 7. The samples which were lowest in silicate (rice fields) were also highest in deuterium enrichment, resulting in a strong negative correlation between Delta D and silicate concentration, Fig. 8. The correlation between bicarbonate and silicate was positive, Fig. 9, due to the relatively low values for both of these constituents in rice fields compared to drainage water.

CONCLUSION

From the obtained results, it could be concluded that the high evaporation from rice field results in increasing stable isotope value yielding the highest values of deuterium to hydrogen ratios which have been observed in Nile Delta agricultural water up till now. Clearly, it will be possible to obtain sensitive indication of the extent of evaporation losses from such fields with careful study, which could be feasible to examine the dynamics of water transport in rice field environment in the future. The high concentration of stable isotopes in the flooded rice field could be used to identify this water separately from water which rapidly drains vertically into the soil. We can consider the drainage discharge, Q, as being composed of two types of components, one experience significant heavy isotope enrichment, while of which

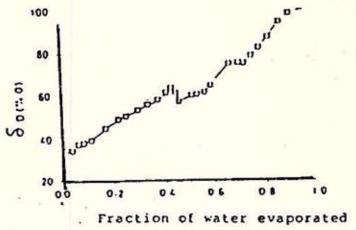


Fig. 3. Sakha evaporation pan SD vs. fraction evaporated.

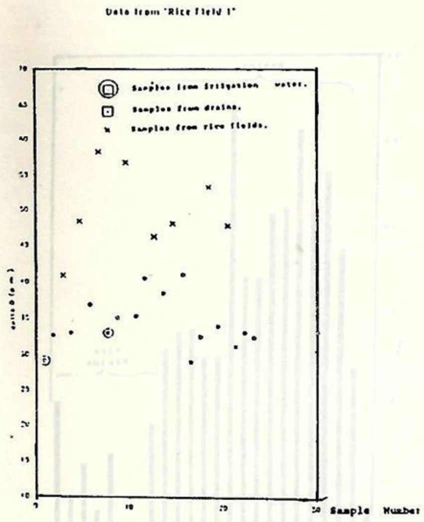


Fig. 4. Deuterium concentration in flooded rice field compared with drains.

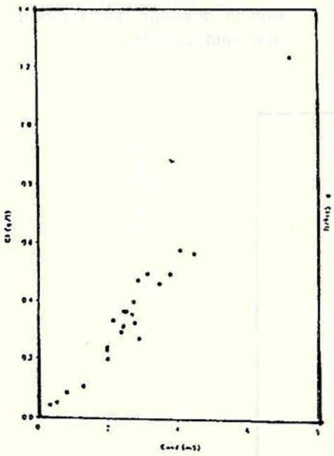


Fig. 5. Relation between chloride concentration and electrical conductivity.

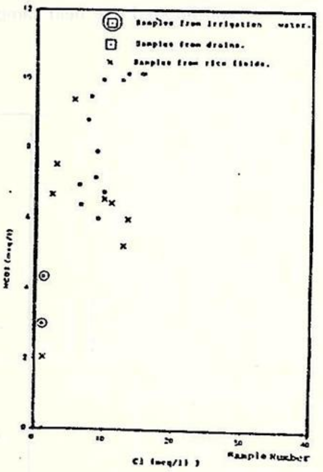


Fig. 6. Relation between bicarbonate and chloride concentration.

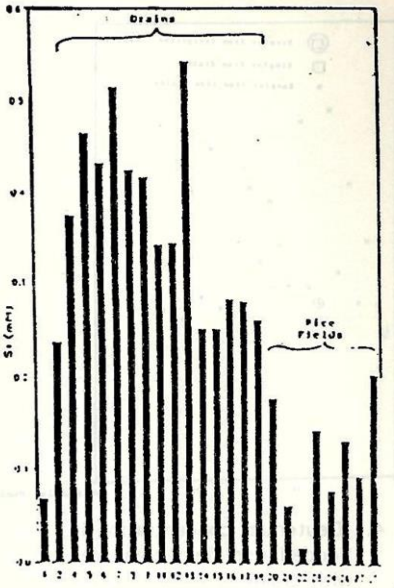


Fig. 7. Silicon concentration in drains and flooded rice field samples.

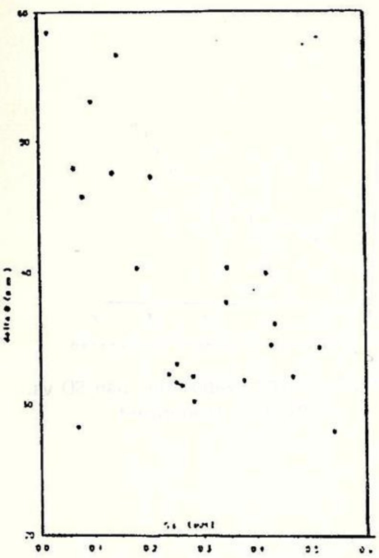


Fig. 8. Relation between Delta deuterium and Silicon concentration in drainage and flooded rice field samples.

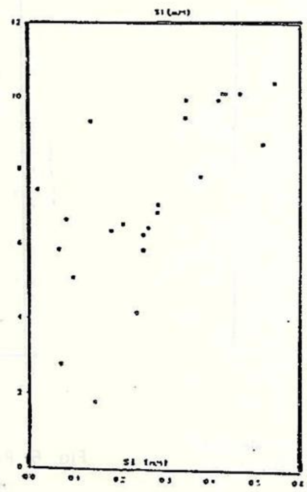


Fig. 9. Relation between bicarbonate and silicon concentration.

the second remains at the surface in rice paddies (P) long enough to activate appreciable heavy isotope enrichment. The (P) component can be distinguished in the total discharge (Q) by conservation expression for both discharge rates and isotope composition. This findings could be helpful in detecting the amount and the effect of evaporation in increasing salt concentration in both rice field water and drainage water.

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تقييم أهمية الفقد عن طريق البخر في زيادة ملوحة مياه الصرف

سامية الجندى ، عطيات أبو بكر

نتيجة للنقص فى مصادر المياه فى مصر .. فقد أصبح لا بد من دراسة امكانية اعادة استخدام مياه الصرف للرى . ولكن غالبا ما تواجهنا صعوبة تحديد مصادر الملوحة فى مياه الصرف وبالتالى صعوبة التنبؤ بمدى التغير المتوقع حدوثه فى المستقبل لملوحة هذه المياه.

تم اجراء هذا البحث لدراسة الزيادة المتوقعة فى ملوحة المياه نتيجة لتعرضها للبخر .. وقد وجد أن حقول الأرز هى أنسب موقع لهذه الدراسة وذلك لان الفقد فى المياه بالبخر فى حقول الأرز اعلى من الفقد الناتج عن النتح من النبات وذلك بالمقارنة بالمحاصيل الاخرى.

ولاجراء هذه الدراسة تم تجميع عينات من حقول الأرز فى مناطق الروضة ونشرت خلال عام ١٩٨٨ وتم تقدير النظائر البيئية (اوكسجين ١٨ ، ديوتريم ، كمية الاملاح ، الكاتيونات والانيونات).

اثبتت الدراسة زيادة المحتوى النظائرى للمياه فى حقول الارز نتيجة للبخر .. وامكن تقدير المحتوى النظائرى وحساب كميات المياه المفقودة بالبخر ، وكذلك تقدير الزيادة المتوقعة فى ملوحة المياه نتيجة للبخر.

وبذلك يمكن دراسة المحتوى النظائرى لمياه المصارف وتحديد مقادير الزيادة فى ملوحتها والناتجة عن البخر وليست الناتجة عن غسيل الاملاح فى التربة.