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LONG-TERM ENVIRONMENTAL TRADE-OFFS IN RECYCLING OF IRRIGATION WATER IN AGRICULTURE

(A Case History in Israel)

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INTRODUCTION

Increased water reuse is inevitable, particularly from the standpoint of conservation demands and economics. Water is simply too valuable to use just once and then discard.

The reuse of untreated recycled water for irrigation purposes in agriculture is probably the most effective response to scarcity of water resources in Israel and many other countries. Although this water conservation strategy represents a very efficient water supply alternative in a country which is considered to be a model of efficient water utilization(1), it does have its long-term environmental trade-offs as far as the irrigated soil and the water in point are concerned.

Indeed, the reuse of untreated recycled water in essentially closed, or semi-closed systems, gives rise to cummulative processes with respect to the quality change of the exploited water. The long-term (and occasionally even the short-term) impact of this change should be preassessed by policy makers.

Based on the current trends for physical growth and the unprecedented challenge to mankind posed by this growth(2), more extensive reuse of water in the 80's is to be expected. This in turn, calls for more and more sophisticated methods in the future efficient reuse of recycled water in agriculture. Consequently, the assessment of the ecological and environmental consequences of such a course of action is a precondition for rational decisions for future planning.

At present, the total irrigated area in Israel is over 200,000 hectares, more than 10% of the area of the country(3). Only a small portion of this area is flood-irrigated by the reuse of recycled water.

Our specific concern was the changes in the natural level and distribution of chemical elements and compounds in the untreated recycled irrigation water in agriculture in an essentially closed system. We have chosen the Beith-Alpha basin in Israel as our site for a model case-history study. Following a previous general-type survey of pollution potential in that area(4), we have conducted base-line studies of the quality of the recycled irrigation water. We have also established the phisico-chemical profile and fluctuations of this water in key points of the system (influents, effluents and reservoirs) over a period of time(5).

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Objective

Evaluate the long-term consequences of the reuse of untreated recycled irrigation water in agriculture in essentially closed systems.

Methods

Determine the pH, conductivity, and concentration of the ions K^+, Na^+, Mg^+, Ca^{2+}, PO_4^{3-}, NO_3^-, and Cl^- in the water sampled at the key points.

SELECTED BASIC DATA OF THE INVESTIGATED SYSTEM

a. Flow Diagram

Fig. 1 is a simplified flow diagram of the investigated system in the Beith Alpha basin. The entire system can be considered as essentially a closed system, although the loss of water via soil and crop absorbtion as well as evaporation is complemented by a few local wells and streams and some accumulated rain water. The numbers in the flow diagram refer to the key-points for water sampling.

b. System Descriptions

Total amount of recycled water: 1.2×10^6 m^3.
Local wells (which supply water to the system): Salt water-75%; Fresh water-25%.
Watershed of the Charod River (in which the irrigated area in located): 182 Km^2.
Total Irrigated area: 400 hectares.
Major irrigated crops: Cotton - 80%; Corn 20%.
Reservoirs capacity: Old Lake - 7×10^5 m^3; New Lake - $4.6 \times 10^5 m^3$.
Distribution of returning water: Northern Channel - 20%; Charod River - 70%; and Southern Channel - 10%.

SELECTED RESULTS

A representative full profile of the quality of the recycled irrigation water in the Beith Alpha basin - as determined by means of water sampling and analysis is given in Table 1. The tabulated data refer to the main key points of the system and represent characteristic situations for both winter (sampling and analysis as of 1/2/78) and the end of the spring (sampling and analysis as of 7/5/78). The corresponding calculated values of the S.A.R.(6) which reflects the ratio between the sodium cations and the sum of magnesium and calcium ions

(i.e. $\dfrac{[Na^+]}{\sqrt{\dfrac{[Mg^{2+}] + [Ca^{2+}]}{2}}}$) are also shown. Complementary data are given for the sake of comparison. All the given water parameters are important to agriculture (crops raising) in terms of short- and long-range consequences(7).

The concentrations of chlorides in each major component of the investigated system are given separately in Figure 2, in order to illustrate the environmental "trade-offs" in the reuse of irrigation water.

DISCUSSION AND SELECTED CONCLUSIONS

Both chloride content of irrigation water and electrical conductivity (reflecting the total amount of soluble salts) are determining factors as far as the long range effects on the irrigated soil - and in turn on the crops raised - are concerned. The permissible limits in water suitable for safe irrigation of most crops in most types of soil are 150 ppm and $0.1-0.25\ m\Omega^{-1}cm^{-1}$ (C_1 category) respectively. Consequently, both the chloride content and the electrical conductivity of the water being tested are far above the permitted standards for irrigation water in agriculture. Their constant increase endangers both the irrigated soil and future crops. These high salinity and conductivity are expected to increase in the investigated irrigation system and in similar systems elsewhere as well, meaning that in the long run the continuous salination of the irrigated soil is unavoidable.

In view of the good correlation between the chloride content and the corresponding electrical conductivity, the later may serve as a reliable probe of the former. Also, it can be safely speculated that the conductivity of the irrigated soil would be found to correlate well with the conductivities of the water used.

Although the calculated S.A.R. values fall within the acceptable range of water quality suitable for irrigation in all kinds of soil (i.e. group S_1 characterized by S.A.R. values between 0-10), they do approach the permitted "red line", causing dangerous changes in the irrigated soil structure. Such a change may lead to a formation of hard and large soil aggregates, a lessening of air permeability into the soil and a limited movement of the water through the soil.

Finally, the substantial wash-out of nitrogen-containing fertilizers may result in euthrophication in the various components of the irrigation water system, particularly in the open reservoirs. This factor in flood-irrigation should be taken into consideration with respect to possible long-range effects.

SUMMARY

The reuse of untreated recycled water for flood irrigation in man-made semi-closed systems (appealing both in terms of conservation and economics) has its long term environmental trade offs: undesirable changes in the natural distribution of chemical elements and compounds. The above are the result of commulative processes of past and present operations.

A long-range study of the long-term environmental consequences of the reuse of water in such (and similar systems) is clearly required. In this respect our study should be considered as an illustrative case history that may be served as a first approximation model for such systems.

An interdisciplinary rethinking concerning untreated water re-use is a crucial task ahead for those concerned with the design and planning of future alternatives of water supply.

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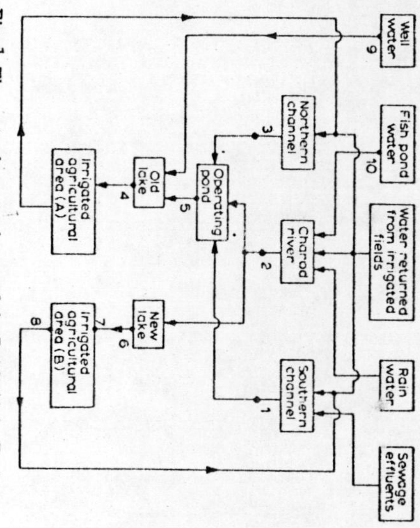


Fig. 1. The water layout scheme of the Beith Alpha Basin.

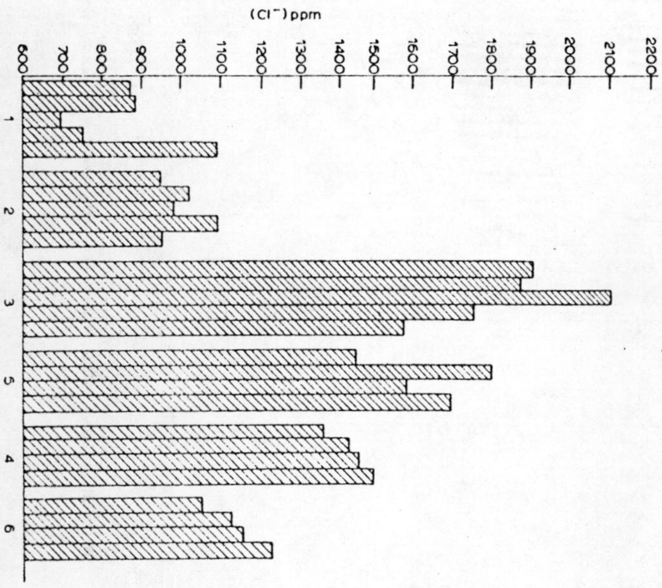


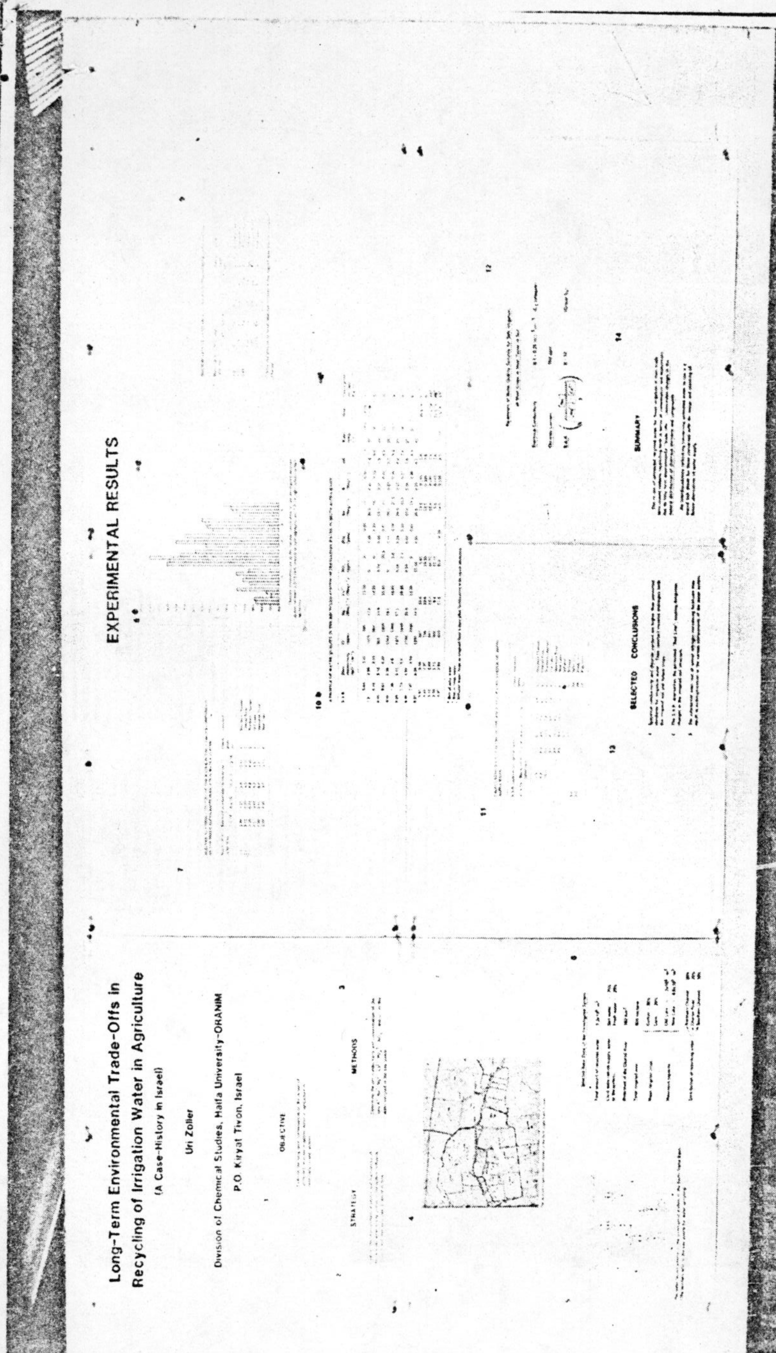
Fig. 2. Chloride concentrations in the various components of the investigated recycled system between 1/2/78 (left column in each aggregate) and 7/5/78 (right column in each aggregate).

TABLE 1

A PROFILE OF WATER QUALITY IN THE RECYCLED SYSTEM OF IRRIGATION WATER IN BEITH ALPHA BASIN

S.A.R.	Elect. conductivity ($m\Omega^{-1}$ cm^{-1})	Cl^- (ppm)	Mg^{2+} (Meq l^{-1})	Ca^{2+} (Meq l^{-1})	NO_3^- (ppm)	PO_4^{2-} (ppm)	Na^- (Meq l^{-1})	K (Meq l^{-1})	pH	Water temp. (°C)	Date	Check point no. (see Fig. 1)
6.64	3.45	880		13.00	0	0.33	17	0.36	7.3	19.5	1.2.78	1
7.3	3.98	1075	15.6		0	0.28	20.6	0.41	7.4	27	7.5.78	
6.44	3.33	960		12.25	0	0.25	16	0.24	8.6	16.5	"	2
6.85	3.52	961	13.9		5.76	0.46	18.1	0.31	7.9	24	"	
9.63	6.35	1900		23.45	20.6	0.27	33	0.31	8.1	22	"	3
9.02	5.39	1563	19.5		0	0.16	28.2	0.22	8.2	25.5	"	
7.36	4.6	1360		16.65	1.6	0.38	21.3	0.36	8.4	15.5	"	4
9.09	5.11	1475	17.1		5.16	0.34	26.6	0.37	8.2	22	"	
7.73	5.0	1440		18.45	5.0	0.48	23.5	0.27	7.8	18	"	5
9.88	5.80	1702	21.0		0.24	0.60	32.0	0.26	7.8	27	"	
7.27	3.54	1040		12.35	0	0.65	18.1	0.36	8.9	21	"	6
9.57	4.28	1237	14.3		11.16	0.32	25.6	0.39	8.1	22	"	
5.67	2.50	667		10.8	5.61	—	13.2	0.195	7.9	—	30.4.78	7
5.45	2.97	756		12.6	15.95	—	13.7	0.320	7.8	—	"	8
5.12	2.69	667		12.5	10.82	—	12.8	0.195	7.3	—	11.4.79	9A[a]
2.53	1.53	301		9.4	11.16	—	5.5	0.110	7.8	—	24.4.78	9B[b]
5.97	2.84	650		11.8	210	0.39	14.5	0.330	8.5	27	9.4.78	8A[c]

[a] Well of salty water.
[b] Well of fresh water.
[c] Effluent water from an irrigated field 4 days after fertilization with liquid ammonia.



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SITE SELECTION TECHNIQUES FOR LAND DISPOSAL OF TREATED MUNICIPAL WASTEWATER

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INTRODUCTION

This paper discusses a low cost methodology for orderly prospecting for, and selection of, a suitable site for disposal by slow rate land treatment-irrigation of treated domestic municipal wastewater. The wastewater is added to the groundwater reservoir and is stored in an unconfined aquifer where it is available for recovery and reuse. Enhanced crop growth is a potential benefit, as well.

The goal is to find a suitable site where long term land application will be feasible without adverse environmental and public health consequences. The development of low-cost site selection methods will tend to promote the land disposal method, as contrasted with high-technology advanced wastewater treatment with subsequent surface disposal. Only minor site modifications are assumed to be feasible.

Slow Rate Land Disposal

Land disposal is a practical method and is a valid conservation technique. The term "slow rate" is used to focus attention on wastewater treatment rather than on irrigation of crops. The rate of placement usually does not exceed five inches per week, average, nor twenty feet per year. In slow rate systems, management of vegetation is a critical treatment component in the management of nutrients. Land treatment of municipal wastewater can be a cost-effective and efficient means of wastewater disposal, pollution control, and resource recovery. In the smaller rural communities of northern Michigan where sand lands predominate, the low volume of wastewater generated, and the relatively economical and available land, are factors that make the land application alternative especially attractive. In addition to meeting the established water quality goals of Public Law 92-500, the system causes vegetative growth to be enhanced, and water to be conserved in the groundwater reservoir.

The Problem-Alternative Solutions

It has not been uncommon historically for municipal and industrial wastewater plants to dispose of treated effluent on the land. Also, septic tank systems place sewage into the ground after only nominal treatment. These wastewaters eventually reach groundwater aquifers. Many of these systems are unplanned. This paper focuses on planned regulated wastewater reuse methods. Wastewater reuse is acceptable