EFFECT OF URBAN DEVELOPMENT ON WATER QUALITY-ENVIRONMENTAL CONCERNS

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ABSTRACT

Urban development increases sewage quantity, which should be treated and discarded. One way of sewage disposal is treating influents and directing treated effluents to agricultural use. This may help in environmental threat while supplying irrigation water to agriculture. However, following a long run use, quality of aquifer can be worsened due to some pollutants remaining in treated effluents. One source is salinity, which is higher in wastewater following domestic use. It may affect soil structure as well as groundwater quality. This effect can be diminished if combining desalinization and wastewater treatment processes. We will assess costs and benefits of wastewater treatment and/or reuse by incorporating desalinization and treatment processes to maintain groundwater quality and prevent environmental aggravation.

Key words: water quality, wastewater, economics, desalinization, urban development

BACKGROUND

Annual water resources in Israel are limited and account to 2,000 MCM (Million Cubic Meters). With the increase of population, domestic demand for water increases, and agricultural supply should be based on marginal water sources (Yaron, 1997). Meanwhile, wastewater sources increase with population growth and should be treated and discarded. Reuse of treated effluents serves as water source for agriculture while acting also as an environmental quality agent.

There are many advantages arising from the use of effluents in agriculture including: i. Treated wastewater will provide for continuity of Israeli agricultural existence under water scarcity conditions. ii. The supply of effluent increases with population growth. iii. The cost of treating secondary effluent is relatively low as compared to other water sources. iv. Reuse of effluent in irrigation is the cheapest option for its disposal in most cases. V. Secondary effluent contains nutrients, which may save on the use of chemical fertilizers (Haruvy et. al., 1999).

There are also disadvantages resulting from reusing wastewater in irrigation related to environmental effects on human health, soil and groundwater (Hadas et. al., 2000; Haruvy et. al., 2000). Also, costs for individual farmers increase reflecting potential damage to crops, adaptation costs of irrigation system and, increased water requirements due to salinity and evaporation at storage reservoirs. Economic cost - benefit analysis will assist in focusing on benefits, costs and damages involved with wastewater reuse (Haruvy, 1997a, 1997b, 1998). Farmers should be motivated by pricing measures to use water efficiently (Tsur and Dinar, 1997) but prices should reflect positive as well as negative externalities of irrigation.

COSTS AND DAMAGES

The costs of transition from irrigation with high quality water to effluent can be classified as financial cost or potential damage to environment, soil, groundwater or crops.

Financial Cost

Financial cost is measured in terms of supply cost of wastewater including treatment, storage and conveyance, or adaptation cost of irrigation system. Table 1 presents the supply cost of wastewater. Capital cost is evaluated according to annual capital return or sinking funds reflecting only depreciation allowance. We assume that in the case of any new element in the supply/irrigation system, which must be installed in transition to effluent, the farmers should receive a full grant to cover the cost. Hence, they should make an allowance only to depreciation fund and not interest return. Anther financial cost refers to the adaptation of the irrigation equipment, e.g. filters, chemicals, and the cost of quality control. They are represented in Table 2 along with their cost estimates.

Table 1: Annual Cost in Transition to Irrigation with Effluent in Terms of Water Supply System (NIS m^{-3}) (1$=4 NIS)

Item	**Capital Return Cost**	**Allowance to Sinking Found**	**Cost Recommended to Farmers**
Treatment Cost			
Secondary Treatment	0.65	0.30	0.00
Conveyance Cost			
Conveyance to Storage	0.09	0.05	0.05
Storage	0.28	0.13	0.13
Conveyance to Fields	0.28	0.12	0.28
Total Conveyance	**0.65**	**0.30**	**0.46**

1) Treatment is up to secondary level. Upgrading up to the tertiary level costs 0.73NIS m^{-3}.

2) "Representative" Scenario: Wastewater volume: 5 million cubic meter, distance to storage: 5 km; distance to fields: 5 km.

Other additional costs to farmers are presented in Table 2. They include storage cost, and, additional costs to irrigation system and leaching.

Table 2: Other Additional Costs to Farmers in Transition to Irrigation with Effluent (NIS m^{-3})

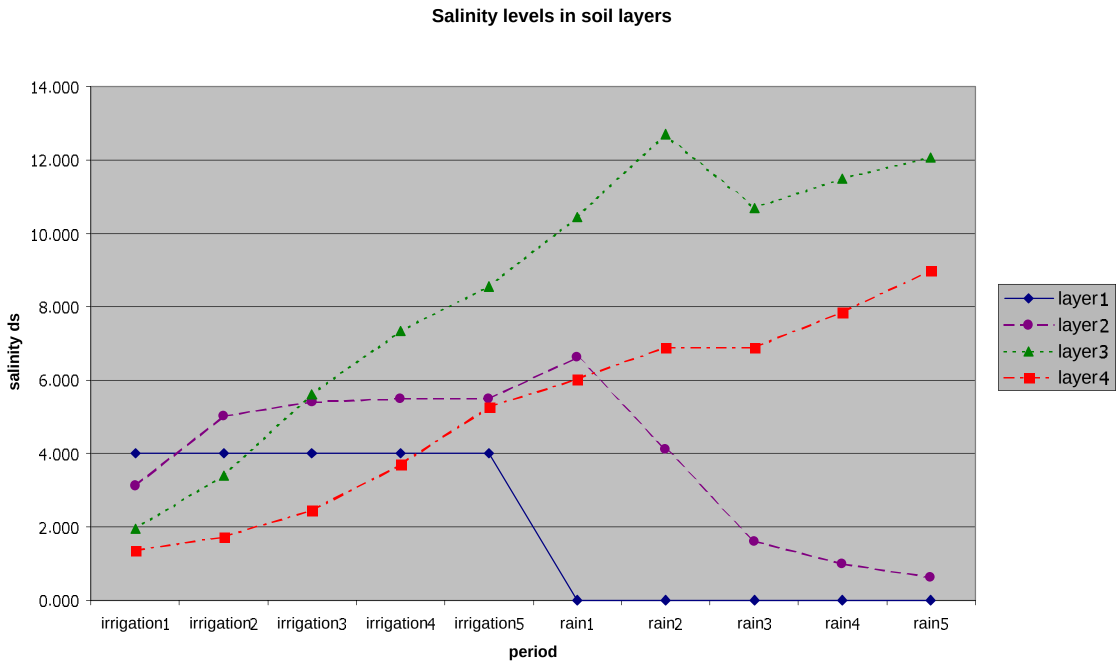
Item	**Annual Cost**
Storage Cost	
10% losses due to evaporation	0.05
Change of quality	n.a.
Follow-up and quality control	0.05
Irrigation system	
Filtration chlorinating chemicals	0.10
Accelerated depreciation	0.02
Maintenance	0.01
Leaching irrigation	
10% of irrigation water	0.05
Soil salinity tests	0.02
Misc. (elimination of most vegetable crops, additional labor, etc.)	
Total additional cost and damages	0.40

Effect on crop yields

We concentrate on factors as salinity in soil solution and nitrogen in wastewater affecting crop yields. Irrigation with saline water including wastewater causes accumulation of salts in the root zone decreasing crop yields. This damage can be partly avoided be leaching, computed conventionally as based on “leaching fraction”. This approach leads to approximate results with respect to leaching effects of rainfall and soil characteristics. When more accurate estimates are required, arises the need to abandon the assumption of steady state and to refer to dynamic conditions prevailing in the soil.

We have designed an initial model aiming at estimating variations of soil moisture and salinity. The model refers to citrus growing in Central Israel. The root zone was divided into 4 layers consuming water at rates of 0.4, 0.3,0.2 and 0.1, respectively. Initial salinity levels were 2, 0 and 1 ds/m in irrigation water, rain and soil. Salinity levels were computed following 5 irrigation and 5 rain periods. Figure 1 presents change of salinity in soil layers (detailed model will be published).

Figure 1: Salinity levels in soil layers



Yield losses increase with soil salinity in the root zone according to crop sensitivity. This salinity can be decreased with increased leaching fraction and crop losses should be compared with additional water cost.

It should be noted that irrigation with secondary effluent including nitrogen (without the application of the nitrification-denitrification module) is advantageous, due to potential saving in nitrogen fertilizers. However, this advantage is relevant only with respect to low-income crops, mainly field-crops. Excessive nitrogen supply in inadequate timing may cause damages to crops e.g., to yield levels and/or yields quality. Potential losses of revenue due to excess of nitrogen have been estimated at 2% in cotton, 6% in avocado, 10% in mango, 11% in citrus Shamouti variety, and 10% in grapefruit, and no damage in corn for forage or silo.

Effect on soil

Soil is affected by salinity expressed as SAR, which is an index representing the ratio between sodium (Na) and calcium and magnesium (Ca & Mg) in water. The major immediate hazard of irrigation with high SAR ratio (SAR>6, EC<4 ds/m) is sodifying the soil surface and deep soil layers. During irrigation cycles, sodium will replace calcium on the soil clay particles and, destabilize the soil structure. This may, and often does, reduce soil surface infiltration to water and drainage of the root zone through lower layers.

The consequences are reduced water uptake into the soil; increased losses of irrigation and rainwater; increased run off; and, ineffective leaching of accumulates salts in the soil root zone affecting yields. Damage can be estimated by costs of additional labor and irrigation water and decreased yields.

Effect on contamination of groundwater

One of the problems involved in irrigation with effluent is the danger of acceleration of contamination of groundwater mainly by chlorides, nitrogen and heavy metals (Wallach, 1994). We designed an approach to the economic evaluation of acceleration on the concentration of chlorides on groundwater due to irrigation with effluent.

The approach is based on hydrological model predicting the flow of chlorides through the unsaturated zone of the subsoil, into the groundwater below. Time needed for the completion of the flow of chlorides inputs through the unsaturated zone, is about 5 years close to the seashore of Israel. It takes about 20 years in the central part of the Coastal Plain, and tens up to hundreds of years in the southern-east part of the Coastal Plain.

A threshold for chloride concentration in the water supply for human consumption was assumed to be 250 mgl. (The current requirement of chlorides is 250 mgl Cl in Israel and 100 mgl Cl in Europe; it is assumed that in the future, the required threshold in Israel will be 150 mgl Cl).

The model assumes that when the concentration of chlorides in the groundwater reaches the threshold of 250 mgl Cl or some value somewhat higher than the threshold, desalination of groundwater should be applied using the reverse osmosis technology.

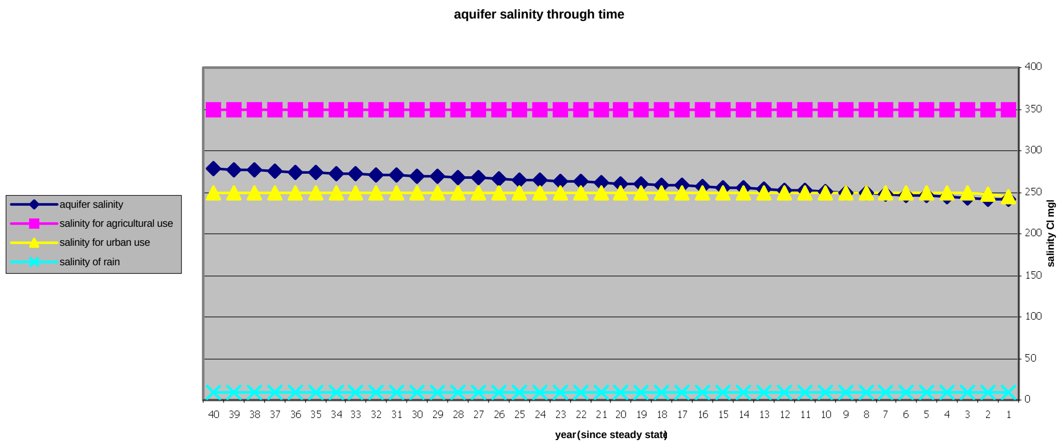
The point of time when desalination should be applied under conditions of irrigation with effluent, as compared with the point of time under conditions of irrigation without effluent, is the basis for the economic evaluation of the damage caused to groundwater by irrigation with effluent. The timing of introduction of desalination (i.e. the level of chloride concentration in groundwater) as well as the level of chloride concentration in the output water of the desalination plant is subject to optimization. The damage to groundwater by effluent irrigation is computed as increased capitalized costs dew to water production, wastewater treatment and earlier desalinization.

We will describe salinity according to scenario 1 based on the following assumptions: Agricultural area 1211 ha with citrus growing, urban area 1052 ha with population of 120,000 inhabitants. Water consumption of agriculture is 9.1 MCM (7,500 CM/ha) and of town is 12.0 MCM (100 CM per capita). Initial aquifer salinity is 250 mgl and domestic threshold is 150 mgl. Wastewater salinity is 350 mgl and rain salinity is 10 mgl. The town uses local aquifer water and agriculture uses treated effluents.
Other scenarios include: scenario 2 in which the town consumes local aquifer water. Imported aquifer water with salinity level of 176 mgl and national carrier water with salinity level of 220 mgl. Agriculture uses aquifer surplus as well as the other two water sources. In scenario 3 the town consumes local aquifer water and national carrier water.

Table 3: Quantity and Salinity of various scenarios

Source	Scenario1		Scenario2		Scenario3	
	Quantity	Salinity	Quantity	Salinity	Quantity	Salinity
Aquifer	488	241	488	241	488	241
Rain (mm)	550	10	550	10	550	10
Wastewater	9.08	350	0.00	350	0.00	350
National carrier	0.00	220	6.95	220	9.95	220
Imported aquifer	4.82	250	6.95	176	3.95	150

Figure 2: Salinity change for various water consumption groups



We computed costs for the three scenarios under the assumption that supply water for the town are desalinized at threshold level of 250 mgl (Table 4).

Table 4: Calculated costs for various scenarios

	Current desalinization cost	Capitalized desalinization cost	Supply cost to town	Supply cost to agriculture	Total supply cost	Total capitalized supply cost
	Present value					
Scenario1	102.40	18.43	489.6	295.1	784.8	273.7
Scenario2	1.66	0.16	471.6	381.1	852.7	310.3
Scenario3	0.73	0.07	517.6	381.1	898.7	327.7
	Annual capital return					
Scenario1	5.61	1.01	26.82	16.17	42.99	15.00
Scenario2	0.09	0.01	25.84	20.88	46.72	17.00
Scenario3	0.04	0.003	28.35	20.87	49.23	17.95

One can see that in scenario 1 which is based on wastewater irrigation, desalinization costs are high because of desalinization advancement. Still, due to lower cost of wastewater, total regional cost of water supply is relatively low. It should be mentioned that final salinity levels of groundwater after 40 years from steady state are 359, 278 and 289 mgl for scenarios 1, 2 and 3, respectively.

CONCLUSIONS

Urban development increases sewage quantity, which should be treated and discarded. Agricultural use of treated effluent assists disposing sewage and keeping environmental quality while supplying irrigation water to agriculture. However, reuse of wastewater may affect crops, soil and aquifer depending on treatment level and irrigation practices. Following a long run use, quality of aquifer can be worsened due to some pollutants remaining in treated effluents for example, salinity, which is higher in wastewater following domestic use. This effect can be decreased when combining desalinization and wastewater treatment processes. We assessed costs of wastewater treatment and/or reuse by incorporating desalinization and treatment processes to maintain groundwater quality and prevent environmental aggravation.

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