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THE JEEZRAEL VALLEY PROJECT FOR WASTEWATER RECLAMATION AND REUSE, ISRAEL

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ABSTRACT

The Jeezrael Valley is one of the richest agricultural regions of Israel, with urban communities in and around the valley. Irrigation in the valley follows the general trend of irrigation in Israel, where potable water is replaced by reclaimed wastewater. In the near future, reclaimed effluent is expected to form 80% of all irrigation water used in valley. This paper discusses a new regional wastewater reclamation and reuse project in the Jeezrael Valley which takes advantage of the proximity of the urban communities to the cultivated areas. The project combines semi-intensive wastewater treatment plants situated near the urban areas with wastewater reservoirs situated in the rural areas. The rationale behind the scheme is discussed and the performance during the first year of operation is presented. During this first year this combined reclamation system was able to release effluent of high quality. The system is expected to release effluent of unrestricted irrigation quality when all its components are installed, enabling the reservoirs to be operated in a full sequential batch mode. © 1999 IAWQ Published by Elsevier Science Ltd. All rights reserved

KEYWORDS

Aerated lagoons; anaerobic ponds; irrigation; sewage treatment; water reuse; wastewater reservoirs.

INTRODUCTION

The Jeezrael Valley consisted mainly of malaria infected swamps until the beginning of the 20th century when it was drained off by the early settlers and transformed into fertile land. Today, with more than 20,000 hectares of intensive cultivated area, it is one of the richest agricultural regions of Israel. The population in and around the valley is concentrated in six urban communities and in numerous small villages. The present population is estimated at about 120,000 inhabitants, and it is expected to reach 250,000 inhabitants by 2010.

Irrigation in the Jeezrael Valley follows the general trend of irrigation in Israel, a densely populated country in a semi-arid region, having limited water resources (Winshtein and Kornberg, 1993; Shwartz, 1996). Until the early seventies, most crops were irrigated with potable water while wastewater reuse was limited. Later on, population growth and increasing water demand led to a growing shortage in the national water budget, while all water resources were already exploited to their maximum capacity. Thus, during the seventies, a decision to drastically reduce potable water supply to the agricultural sector in order to meet the growing urban demand was taken by the national water policy makers. The same decision suggested treated wastewater as an alternative source for the agricultural sector. Indeed, today nationally more than 65% of the municipal sewage is reused for agricultural irrigation.

The Jeezrael valley receives irrigation water from three main sources:

1. Freshwater from Lake Kinneret (Sea of Galilee) through the National Water Carrier.
2. Part of the wastewater effluent of the Haifa Metropolitan area (about 450,000 p. e.) through the "Kishon Complex" wastewater treatment and reuse scheme.
3. Wastewater effluent from towns and small settlements in and around the Valley (about 120,000 p. e.) through the new Jeezrael Valley wastewater treatment and reuse project.

Irrigation with reclaimed effluent is being performed in the valley for more than 30 years, in fact wastewater reuse in irrigation was pioneered here. This practice started with some small local schemes utilising limited amounts of poorly treated wastewater effluent for irrigation of cotton, an industrial crop with low water quality requirements. In 1983, the Valley received 20-30 MCM/y (million cubic meter *per* year) of freshwater from the National Water Carrier and 7.5 MCM/y of effluents from local towns and small settlements. With the commissioning of the "Kishon Complex" scheme in 1984, an additional 6.5 MCM/y of treated effluent from Haifa reached the Valley (Rebhun *et al.*, 1987). By 1990 the Valley received only 7 MCM of freshwater from the National Water Carrier (about 70% reduction), while effluent conveyed from Haifa treatment plant amounted to 11 MCM. The new Jeezrael Valley Project supplied 6 MCM of treated effluent during its first year of operation (1996) and it is expected to supply about 13 MCM/year or more by 2010.

In the near future, reclaimed effluents (mainly from the 'Jeezrael Valley' and 'Kishon Complex' projects) will form 80% of all irrigation water used in the Jeezrael Valley, due to the increase in raw sewage production (resulting from population growth) combined with a decrease in the amount of freshwater allocated for irrigation (due to freshwater shortage).

GENERAL DESCRIPTION OF THE PROJECT

The concept

The new regional Jeezrael Valley project takes advantage of the proximity of the urban communities which 'produce' sewage and the rural areas which 'consume' treated wastewater for agricultural irrigation. The project combines semi-intensive wastewater treatment plants with wastewater reservoirs (extensive treatment units) acting as an integral part of the treatment system. The rationale behind the use of wastewater reservoirs as part of the treatment system is that the reservoirs are needed anyway (to regulate between wastewater "production" which occurs throughout the year and effluent reuse which occurs only during the summer), while utilising them as treatment units will enhance the system's performance and reduce costs.

By incorporating semi-intensive treatment plants with wastewater reservoirs the scheme benefits from the merits of each component, namely:

- The ability of the semi-intensive wastewater treatment plants to remove readily degradable material from sewage in a relatively short time with a rather low energy consumption.
- The ability of the wastewater reservoirs to further remove degradable material and to remove slowly degradable material and other refractory pollutants (Juanico and Shelef, 1994; Liran *et al.*, 1994; Juanico *et al.*, 1995; Friedler and Juanico, 1996).

Figure 1 depicts a schematic map of the master plan of the project. It should be noted that the project was not designed from scratch, but was based on an existing situation where many reservoirs were already constructed as a result of local initiatives for flood water and wastewater utilisation. Thus, the spatial distribution of the reservoirs could not be optimised. The main components of the scheme are listed herewith:

- 5-6 semi-intensive sewage treatment plants for the treatment sewage from towns and settlements in and around the Valley. These treatment plants are situated in the proximity of the urban centers. The treatment plants consist of anaerobic ponds followed by aerated lagoons and are designed to release effluent with BOD levels not exceeding 80 mg/l.
- Main conduits which inter-connect the treatment plants and connect the plants to a network of wastewater reservoirs situated in the rural cultivated areas (22 reservoirs in stage I of the project). The conduits enable conveyance of effluent from any treatment plant to any reservoir.
- Wastewater reservoirs to be operated in SBR (sequential batch reactors) mode, either in series or in parallel in order to obtain high quality effluent.
- Disposal-reuse of the treated effluent *via* agricultural irrigation within the Valley.

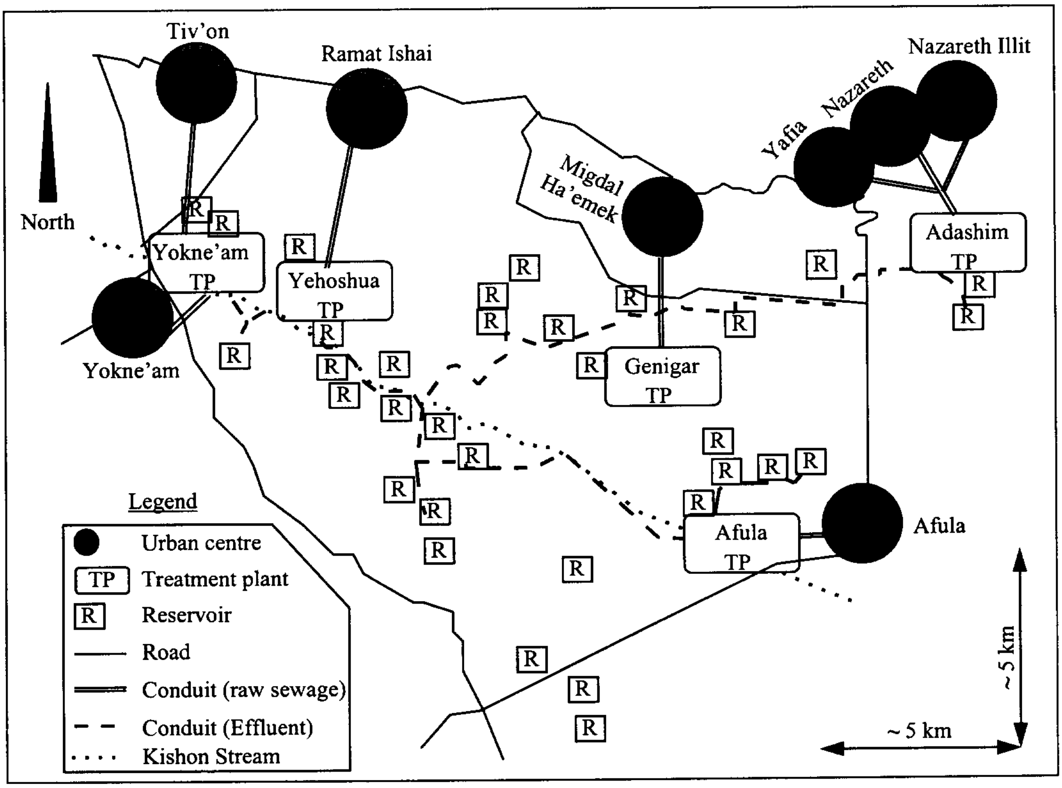

Figure 1. The Jeezrael Valley Project - Schematic Map of the Master Plan. Adapted from: Palgey Ma'im (1992).

The reality during the first year of operation - 1996

During the start-up and first year of operation of the project (1996) only three treatment plants were commissioned (Adashim, Genigar & Yehoshua), while a fourth one (Yokne'am) was under construction.

- Adashim treatment plant, which treats mainly the sewage of Nazareth and Nazareth Illit and their industrial zones, consists of three anaerobic ponds in parallel of 10,000 m^3 each, followed by three aerated lagoons in parallel of 12,000 m^3 each. The plant does not have any pre-treatment unit.

- Genigar treatment plant treats the sewage of Migdal Ha'emek and its industrial zones. The plant consists of screen bars as a pre-treatment step, followed by three parallel anaerobic ponds of 26,000 m^3 each, ending with two aerated lagoons in series of 30,000 m^3 and 26,000 m^3. Only two anaerobic ponds were operated during the first year due to underloading of the plant.

- Yehoshua treatment plant (which is the smallest of all three) treats mainly the sewage of Ramat Ishai. Raw sewage entering the treatment plant consists mainly of domestic sewage and a relatively small proportion of industrial and commercial sewage. The plant comprises of screen bars as a pre-treatment step, followed by two anaerobic ponds of 2,100 m^3 each (in parallel), ending with a single aerated lagoon of 8,000 m^3. Only one anaerobic pond was operated during the first year due to underloading of the plant.

During this first year of operation, only part of the conduits connecting the treatment plants and the wastewater reservoirs were already laid. This inflicted major constraints on effluent distribution to the reservoirs, and on the operation of the reservoirs in a full SBR mode. However, in spite of these constraints, the project succeeded to treat, store and supply about 6 MCM of treated effluent for agricultural irrigation (Friedler *et al.*, 1996).

SYSTEM PERFORMANCE

Quantity and quality of raw sewage

Quantity. Sewage flow into Adashim and Genigar treatment plants averaged about 10,000 and 5,500 m^3/d respectively. While no seasonal pattern was found to exist in raw sewage inflows into the above treatment plants, inflow to Yehoshua treatment plant increased steadily throughout the first year of operation (from about 450 m^3/d at the beginning of this period to about 1,000 m^3/d at its end). This significant increase was due to massive population growth in the settlements connected to the plant.

The diurnal pattern of raw sewage inflow also differed between the first two treatment plants and Yehoshua plant. The diurnal variation of raw sewage inflows entering Adashim and Genigar treatment plants is typical of municipal areas having significant industrial and commercial contribution. This is expressed by early morning minimum (4-6 am) followed by a long high-inflow period during the day (10 am-10 pm) after which a steep decrease occurs until the morning minimum. The diurnal variation of raw sewage inflow entering Yehoshua treatment plant is typical of smaller settlements, as expressed by sharper variations i.e. steep morning maximum (10 am), followed by a period of low flow (12-7 pm), an evening maximum (10 pm) which declines towards the early morning minimum at 4-6 am.

Quality. Table 1 presents average values of the quality parameters defining the raw sewage entering the treatment plants. Adashim treatment plant received the strongest sewage with COD_{total} and BOD_5 of about 1,200 and 600 mg/l respectively, while the raw sewage reaching the other two treatment plants was somewhat less polluted.

Quality of raw sewage reaching all treatment plants exhibited significant weekday/weekend variations. In general, during the week all concentrations were higher than during the weekend, a phenomenon which occurs in raw sewage which has a significant industrial component (most factories do not operate during the weekend). In Genigar treatment plant highest weekday/weekend variation was observed, with weekday/weekend ratios of the daily average concentrations of COD_{total}, $COD_{dissolved}$, BOD_5 and TSS being 1.35, 1.67, 1.59 and 1.36 respectively. The Adashim treatment plant serves a mixed population of Christians, Jews and Muslims having different weekend days (Sunday, Saturday and Friday respectively). Thus the weekday/weekend ratios were somewhat lower at 1.26, 1.10, 1.08 and 1.07 respectively. No significant variations were found between the weekday and weekend average daily concentrations in Yehoshua treatment plant. This was due to the fact that this treatment plant received domestic sewage mainly.

Sewage quality exhibited strong diurnal variation, with low concentrations observed in the early morning hours and high concentrations observed during day-time. Figure 2 depicts the diurnal variation of COD. Other parameters displayed the same general trend. The ratio between maximum and minimum concentrations (on an hourly basis) were between 2 to 3.5 for COD, BOD and TSS in all three sewage streams, while the maximum to minimum ratio of toxicity inhibition (bacteria-based toxicity test) was about 1.4-1.6.

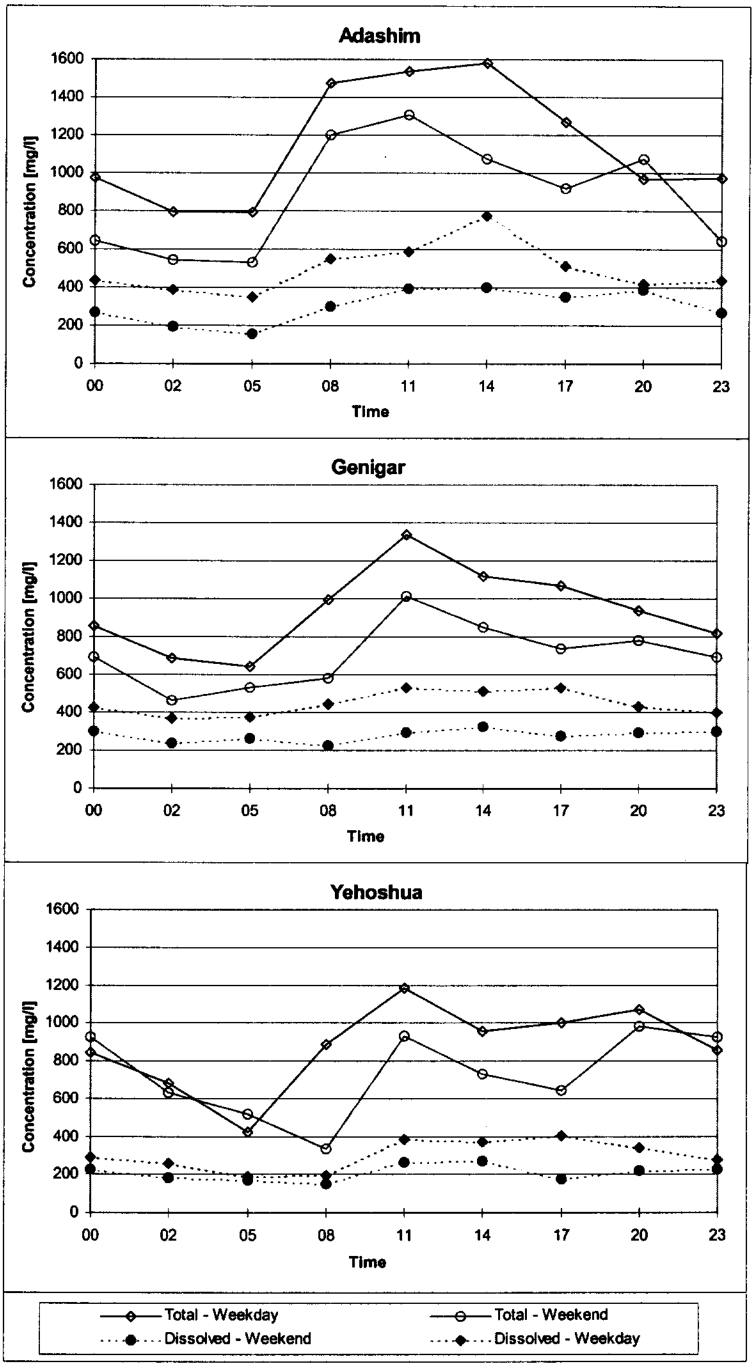

Figure 2. Diurnal variation of COD concentrations in the raw sewage.

Several industrial zones reside in the urban centers surrounding the Valley. The industries include food production, chemistry, electronics, high-tech, metal plating, plastics, etc. Although the discharge of toxic effluents from the factories into the municipal sewer network is restricted by law, only limited information on the actual concentration of toxic compounds in the sewage released from the factories was available. Moreover, it should be noted that modern municipal sewage contains numerous toxic compounds of domestic and non-industrial sources, each one appearing at a very low concentration, but with potential accumulative toxic effect (Friedler and Juanico, 1996). Thus, raw sewage reaching all treatment plants during the start-up first year was classified as moderately toxic (i.e. within the 20-50% inhibition range in a bacterial based toxicity test - *Luminescent Bacteria Test, DR Lange GmbH, Berlin, Germany*), with raw sewage reaching Adashim treatment plant having the highest levels (46% inhibition on average, peaking to 52% - high toxicity) and raw sewage reaching Yehoshua treatment plant having the lowest levels (32% inhibition on average).

Table 1. Flow capacity, organic loads and performance of the Jeezrael Valley sewage treatment, storage and reuse project

Treatment step	**Parameter average value**	**Units**	**Adashim treatment plant**	**Genigar treatment plant**	**Yehoshua treatment plant**
Raw sewage	Flow	m3/d	9,850	5,520	1,000
	COD total	mg/l	1,175	960	910
	COD diss	mg/l	475	440	300
	BOD 5	mg/l	625	435	450
	Toxicity	% inhibition	46	37	32
Anaerobic Ponds	Residence time	days	3.1	9.6	2
	Organic load	g BOD/m3/d	200	46	200
	COD removal	%	33	45	46
	COD removal	g COD/m3 of pond volume /d	136	162	150
	pH		7.0	7.2	7.2
Aerated Lagoons	Residence time	days	3.7	10.3 (5.5 + 4.8)	8
	COD removal	%	37	65 (47 + 34)	53
	COD removal	g COD/m3 of pond volume /d	82	72 (98 + 43)	47
Anaerobic ponds + Aerated Lagoons	outflow COD	mg/l	470	185	230
	outflow BOD	mg/l	110	25	23
	COD removal	%	60	82	65
	BOD removal	%	82	95	95
	outflow Toxicity	% inhibition	15	10	15
Wastewater Reservoirs	outflow BOD	mg/l	10	8	15
	outflow Faecal colif.	number/100 ml	1.3E3	1.4E3	1.7E3
	outflow Toxicity	% inhibition	4	7	5
	outflow EC	mmhos/cm	1.58	1.97	1.91
	outflow Boron	mg/l	0.42	0.39	0.33
System performance	BOD removal	%	98	98	99
	Toxicity reduction	%	91	81	84

Semi-intensive treatment plants performance

Two out of three treatment plants (Genigar and Yehoshua, Table 1) released effluent with average BOD about 25 mg/l which was lower than the design value of 80 mg /l, these plants had BOD removal rate of 95%. The performance of the third treatment plant (Adashim) was poorer and it released effluent with average BOD about 110 mg/l. Further, all treatment plants succeeded to lower the toxicity level to 10-15% inhibition, a level below toxic threshold (20% inhibition).

Adashim treatment plant. The treatment plant operated during 1996 almost at its maximum loading capacity, while its performance was fair (82% and 60% BOD and COD removal respectively), and thus the design effluent quality was not reached. The inadequate performance of the anaerobic ponds was the limiting factor of the overall performance of the plant, while the aerated lagoons exhibited good performance. Two factors were responsible for the poor performance of the anaerobic ponds: the pH within the ponds which was lower than 7.3 (the minimum recommended value), and the hydraulic regime in the ponds (it is suspected that the ponds suffered from dead-volumes and short circuiting, and winter overloading).

While surveying some of the factories in the industrial zones of Nazareth Illit one food manufacturer was found to release industrial sewage with high COD loading, which is equivalent to 30% of the towns' total load. This sewage is also highly toxic (70% inhibition). Adequate pre-treatment and source control at the factory will reduce significantly the organic load and the toxicity of the raw sewage entering Adashim treatment plant and will enhance its removal efficiency.

Genigar treatment plant. Although during 1996 only two anaerobic ponds were operated, the plant as a whole was underloaded. The removal ratio in the plant is very high and the quality of released effluent is much higher than the design quality. Peaks of COD and TSS which were occasionally observed in the effluent resulting from algae growth within the underloaded anaerobic ponds (having mean residence time of 9.6 days and organic loading of 46 g-BOD/m^3/d). These algae continued to grow within the aerated lagoons, and thus were released with the effluent. In order to overcome this occasional problem, it was suggested that at the consecutive years (1997-98) only one anaerobic pond should be operated while keeping the mean retention time in the anaerobic step to less than 5 days.

Yehoshua treatment plant. The performance of the plant was good and the effluent released was of higher quality than the design value. The anaerobic pond that was operated (out of the 2 existing ponds) was reaching its maximum loading capacity by late 1996 (having mean residence time of 2 days only and organic loading of 200 g-BOD/m^3/d), while the aerated lagoon was still largely underloaded. It was suggested that in the consecutive years (1997-98) both anaerobic ponds should be operated. This will result in better removal during the anaerobic stage, and this will enable the saving of energy needed for aeration of the aerated lagoon while keeping the high quality of effluent.

Stabilization reservoirs performance

All reservoirs released effluents with $BOD_{5\ total}$ ranging between 8 and 15 mg/l, a quality matching the Israeli guidelines for unrestricted irrigation. The reservoirs further succeeded to lower the level of toxicity from about 10-15% inhibition in the influent to 4-7% inhibition in the effluent - a negligible inhibition. However, the bacteriological quality of the effluent was somewhat poor (about 1.5E3 Faecal coliforms/100 ml), and from this aspect the effluent suited only restricted irrigation (i.e. irrigation of peel fruits, shell nuts, animal fodder, wheat, industrial crops etc.). This resulted from the inability to operate the reservoirs in a real SBR mode, due to the quoted temporary constraints in the availability of effluent conduits.

CLOSING REMARKS

The wastewater reclamation and reuse scheme of the Jeezrael Valley treated about 6 MCM in its first year of operation (1996), and will be capable to reclaim 13 MCM/y at full development. The scheme, which is based on an existing situation, succeeds to combine semi-intensive wastewater treatment plants with wastewater reservoirs (extensive treatment units). By integrating the reservoirs into the treatment system and operating them as SBR reactors it was possible to enhance the system's performance and reduce costs.

Further, this integration enabled us to benefit from the merits of each component, namely: the ability of the semi-intensive wastewater treatment plants to remove readily degradable material in relatively short time and rather low energy consumption; the ability of the wastewater reservoirs to further remove degradable material and to remove slowly degradable material and other refractory pollutants.

During the first year of operation this combined system was able to release effluent with low BOD_5 concentrations (8-15 mg/l), while Faecal coliform removal was somewhat deficient. This was a result of temporary constraints not enabling operation of the reservoirs as real SBR reactors. It is expected that when the reservoirs will be operated as real SBR reactors (Juanico, 1996) this regional reclamation and reuse scheme will be able to provide effluent of a quality good enough for unrestricted irrigation.

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