

WASTEWATER REUSE – RISK ASSESSMENT: THE ISRAELI CASE STUDY

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Abstract

Wastewater treatment plants in Israel treat approximately 500 million cubic meters a year. The high quality treated wastewater is used mainly for large scale agricultural irrigation. Israel, which is considered to be a leading country in the world in technologies for treated wastewater use in agriculture, has acquired much experience in adjusting the treatment level of the wastewater treatment plants and the qualities and characteristics of the treated wastewater to land and crops.

The economic advantage of utilizing the treated wastewater in agriculture substantiates the policy of assisting recycling plants and farmers, with the reuse of treated wastewater enabling the conversion of expensive freshwater. Reuse of treated wastewater involves several types of risks: Health, Environmental, Economic and Strategic.

It is difficult to measure these risks. An attempt was made in this presentation to map them out and create a basis of understanding for the continuation of the work plan that will create financial functions representing various risks. However, when making such an analysis, one must consider the cost of avoiding the development of a treated wastewater supply project. In Israel, we are taking the risk because we are convinced that this cost is much higher.

Key words: wastewater treatment, treatment plant, decision making, risk assessment, financial costs.

1. The need

Over the last decade there has been a rapid growth, in the developed world, in environmental public awareness. A lot of human and financial resources are being invested in solving environmental issues such as sea and rivers contamination by sewage flow.

Israel is one of the driest countries in the world, along with other Middle East and North African countries (MENA – Middle East North Africa), it is facing another related serious environmental issue - a continual lack of fresh water [1].

The drought is a meteorological and hydrologic nature phenomenon. It is also a circulatory phenomenon, with no ability to predict its recurrence or its length. Treating wastewater is meant to deal with these two issues:

1. It significantly reduces sanitary – ecological nuisances, thereby allowing a sustainable policy.
2. Reclaimed wastewater can be used for agriculture and city irrigation, if treated properly.

The process, according to which, more and more agricultural areas will be transferred from being irrigated with fresh water (introducing seawater desalination cost) to irrigation with treated wastewater, is powered using a combination of economic means (the price of the recycled water is lower than the price of fresh water), legal tools (reducing quotas for fresh water), and advantages of reliability (supply of effluent is not influenced by climate, hydrology, etc).

Apparently, the way has been cleared for the process. The quantities of treated wastewater, and probably even larger quantities in the future, will serve as an appropriate resource for agricultural development in Israel, duly with achieving additional goals of developing settlements, preserving open spaces and natural resources, etc.

2. The Quantities of Treated Wastewater

The use of treated wastewater in Israel is one of the highest rates in the world. The State of Israel has achieved some impressive accomplishments in reclamation and reuse of wastewater, and at solving issues which arose from using treated wastewater (effluent). Effluent has been an integral part of Israel's water resources for some time. The total amount of wastewater produced in Israel is approximately 500 million cubic meters a year (mcm) including agriculture, industry, and other wastewater consumers.

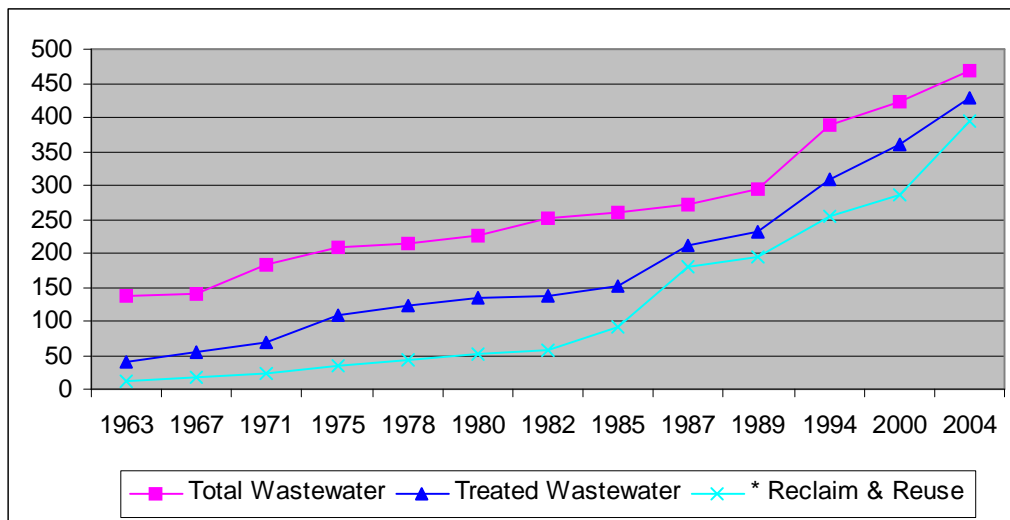
Almost all of the wastewater produced in Israel flows into the main sewage collection systems, while only 2.5% of the wastewater still flows into cesspits. Approximately 450 mcm, is being treated at 465 mechanical facilities and stabilization basins, using a variety of technologies. Approximately 350 mcm of the effluent, which is 80% of the total wastewater, is at least at 20 (BOT)/30 (TSS) quality (explanation about the qualities is given in the next chapter), and approximately 150 mcm of the effluent, which is 20% of the total quantity, is at improved, 3rd degree quality. 300 mcm of wastewater, which is $\frac{2}{3}$ of the total treated wastewater, is reclaimed for irrigation.

The following table and chart present the quantities of wastewater, effluent and reuse over the years 1963-2004.

Table 1: Quantities of water

Year	Million cubic meter a year			% of Total	Irrigated area (dunams)
	Total Wastewater	Treated Wastewater	Reclaim & Reuse		
1963	137.3	41.1	10.2	7%	15,000
1967	139.4	53.5	16.4	12%	20,700
1971	183.2	68.7	22.2	12%	30,400
1975	209.3	108.3	34.2	16%	51,000
1978	213.9	121.8	43.4	20%	68,600
1980	225.8	133.4	52.3	23%	88,200
1982	251.2	137.3	57.1	23%	100,000
1985	259.7	151.7	91.8	35%	163,000
1987	270.1	212.3	180.4	67%	257,700
1989	293.1	232.4	194.9	66%	278,400
1994	389.0	309.4	254.2	65%	363,100
2000	422.4	360.0	285.2	68%	440,900
2004	469.3	427.7	395.0	84%	705,252

Figure 1: Quantities of water



Over the last ten years the following significant changes have occurred:

- A 20.6% growth in the amount of the wastewater.
- A 24% increase in the capacity of the sewage systems.
- A 67% decrease in the disposal of wastewater by cesspits.
- A 37% increase in the amount of wastewater treated by the facilities.
- A 70% decrease in the untreated wastewater flowing to the rivers.
- A 55% increase in the reclamation and reuse of effluent.
- A 76% growth in the areas irrigated by effluent.

Effluent reservoirs make it possible to supply all year long, and to adjust the supply according to the irrigation season. Using effluent gives the consumer supply stability, with no concern about shortage due to drought. In addition, the limited amount of available fresh water for irrigation, the growth of the urban and industrial sectors, which require fresh water, and the high price of desalinated sea-water, cause the effluent to become a growing part of the available water sources for the agricultural sector.

As to environmental aspects, the use of effluent for irrigation is desirable due to the following reasons:

1. Decrease of the pressure on the fresh water resources.
2. Disposal of the treated wastewater while preventing environmental damage to rivers and the sea, etc.
3. Improved stability of the flow in streams.

Bellow is a summary of the national water balance table for the years 1999, 2002, 2005, 2010:

Table 2: Water balance

Year	Water Resources-mcmy		Effluent Consumption-mcmy			
	Reclaimed Wastewater	Total Demand	Industry		Agriculture	
			Effluent	Total	Effluent	Total
1999	278	1,915	0	126	278	
2002	298	1,966	0	129	298	1,010
2005	403	2,417	0	140	403	1,062
2010	509	2,541	13	167	496	1,122

By the beginning of the next decade the wastewater treatment facilities in Israel will be dealing with approximately 509 million cubic meters of treated wastewater a year, from which approximately 496 million cubic meters will be reclaimed for

agricultural irrigation use. The development of the effluent quantities is more moderate at the end of the decade, because it evolves from natural growth of effluent in existing projects, rather than from initiating new projects, at the beginning and middle of the present decade.

3. Qualities of Treated Wastewater

A special committee was recently established in order to define the required quality level of the effluent. This committee has submitted its recommendations for utilizing the treated wastewater for unlimited irrigation and improvement of the effluent flow to the rivers and sea. These recommendations were widely adopted and have received a government decision validation. A draft law proposal is now being prepared according to the Committee's principles. Although these quality standards are not yet obligatory, it is required that future as well as existing wastewater treatment plants achieve this quality level.

Following below is the maximum level of the main parameters for unlimited irrigation and for rivers flow, according to the Committee.

Table 3: Main parameters

Parameter	Units	Unlimited irrigation	Rivers flow
Electrical conductivity	dS/m	1.4	
BOD	Mg/L	10	10
TSS	Mg/L	10	10
COD	Mg/L	100	70
Nitrogen (ammonia)	Mg/L	20	1.5
Nitrogen (general)	Mg/L	25	10
Phosphorous (general)	Mg/L	5	1.0
Chloride	Mg/L	250	400
Koli	Units/100mL	10	200
Boron	Mg/L	0.4	

4. The Economics of Treated Wastewater

I will present investment wastewater treatment plans and reclamation projects

Table 4: Wastewater Treatment Plants

		Quality Level	
		SBR*	3 rd degree
Investment			
Average investment at cubic meter per day	Plant Production		
	5,000 cubic meter / day	~ 0.78 \$/cm	~ 1.04 \$/cm
	50,000 cubic meter / day	~ 0.31 \$/cm	~ 0.44 \$/cm
Cost to cubic meter			
Costs	Plant Production		
Capital Cost	5,000 cubic meter / day	~ 0.17 \$/cm	~ 0.23 \$/cm
	50,000 cubic meter / day	~ 0.07 \$/cm	~ 0.095 \$/cm
Operation Costs	5,000 cubic meter / day	~ 0.13 \$/cm	~ 0.22 \$/cm
	50,000 cubic meter / day	~ 0.088 \$/cm	~ 0.15 \$/cm
Total	5,000 cubic meter / day	~ 0.30 \$/cm	~ 0.45 \$/cm
	50,000 cubic meter / day	~ 0.16 \$/cm	~ 0.25 \$/cm

* Sequencing Batch Reactor

Table 5: Reclamation Projects

Total investment in Israel of wastewater reclamation projects through the years 2001-2006	Approximately 350 million US \$
The State participation from the the total investments	Approximately 200 million US \$
Avarage entrepreneur base cost per cubic meter	~ 0.28 \$/cm
Avarage entrepreneur cost, after the State's participation, per cubic meter	~ 0.15 \$/cm

5. Risk Assessments

The experience acquired in the water sector concerns the broadest entirety of the work comprising the initiative, planning, financing, construction and operation of the treatment plants and the use of the recycled water in agriculture. This

experience presents certain risks for the administration to consider. It is our intention to map out these risks, and to examine consequences and evaluations in order to learn more about this subject.

The risks involved in using treated wastewater are of several types:

- Public Health
- Environmental
- Economic

Following is a brief description of the possible risks:

5.1 Human health risks

Wastewater irrigation poses a number of potential risks to human health via consumption or exposure to pathogenic microorganisms, heavy metals, harmful organic chemicals such as endocrine disrupting compounds and pharmaceutically-active compounds. Of these, pathogenic microorganisms are generally considered to pose the greatest threat to human health. Household sewage contains a high percentage of organic materials and pathogenic microorganisms, including bacteria, viruses, protozoans and parasitic worms. The symptoms and diseases associated with such infections are also diverse and include typhoid, dysentery, gastroenteritis, diarrhea, vomiting and malabsorption. Any human contact with the treated wastewater might be hazardous. In addition, sprinkler irrigation could cause spray drops that contain pathogenic materials, which might cause a health risk to the population, if irrigated next to roads or inhabited areas. The process at the treatment facilities reduces the pathogenic micro-organisms content, but it does not eliminate it completely. This problem can be solved by desalination of the treated wastewater, but this is an expensive process and is usually not required from the aspect of agricultural use.

Different crops that are irrigated by recycled wastewater pose various threats to human health. There are crops with pathogenic micro-organisms contamination that do not seem to pose any health risk:

- Industrial crops such as cotton or fodder.
- Fruits that are dried in the sun for at least 60 days after last irrigation.
- Watermelons grown for edible grains or for seeds, that are irrigated only before blooming.
- Groves or flora, without human access. .

The agricultural system, which includes land and crops, is defined in the planning stages of the recycling supply system. Each land and crop

has its own irrigation quality permit. The law requires the receipt of a permit from the Ministry of Health, for every treated wastewater irrigated land or crops. As mentioned above, the established committee regulations pose a set of high quality standards, for unlimited irrigation, which are supposed to prevent any potential health risk from eating treated wastewater crops or exposure to the effluent.

It appears that there are unknown risks where the quality of the treated wastewater is unsuitable. It is not always possible to solve such a condition except with substantial means, financial or others.

An additional potential health threat might happen if a cross connection between the effluent and the fresh water piping systems occurs. This situation poses a risk of a massive disease outburst, because it could insert the microbiological contamination directly into the fresh water piping system. Regulations were made in order to prevent this hazardous situation.

5.2 Environmental Risks

Irrigation with treated wastewater might add certain contaminants, such as chlorides, to the groundwater [2]. This risk has an accumulative nature as the contaminants appear in the water supply systems, flow to the treatment plants and back to the aquifer. The risks in this respect have a long-term influence and are difficult to evaluate.

According to the health regulation treated wastewater irrigation is forbidden in the vicinity of drinking water wells (except for effluent that does not pose any risk). In addition, treated wastewater irrigation along the national water carrier route (from the Sea of Galilee) is completely forbidden. Irrigation above fresh water pipes can be approved, only if the treated wastewater is at the needed quality level, if the water pipe is in good condition and there is no risk of under-pressure in the pipe. Untreated wastewater systems must have a minimal distance of 3 meters from the irrigated area end point to the fresh water pipe.

In addition to microorganisms, household sewage also contains also substantial salts additions [3]. Besides the risk to the quality of the ground water due to seepage, irrigation with treated wastewater causes land salinity. Treated wastewater irrigation also causes land sealing and sodium accumulation, which could cause increased run off and lands erosion. The above mentioned regulations for the treated wastewater quality, deal with these issues as well.

Other potential environmental effects

- Poor quality treated wastewater, or treated wastewater that is being sucked from anaerobic layers of the treatment plant's reservoir could cause a strong odor nuisances.
- Irrigation with treated wastewater, if not properly controlled, could cause a decrease in yield, as well as in the quality of the crops.

5.3 Economic Risks

Unbalanced supply – demand - In the recycling supply system, the water source is fully managed and controlled quantitatively. On the other hand, agricultural demand is based on substantial uncertainty and may fluctuate significantly. Possible reasons for a demand reduction could be: the farmers abandoning their fields due to economic losses and/or shortage of low-salary workers, a change in designation of the agricultural areas for real estate purposes, marketing problems abroad which are attributed to the unapproved water source, etc.

A situation in which a rapid decrease in demand occurs could cause a substantial lost of money to the entrepreneur, which would have to flow the extra treated wastewater to the sea, with no compensation. This situation might lead to a risk of closing the treated wastewater facility due to economic issues.

On the other hand, a situation in which there is not enough supply to meet the demand will cause shortage damages. The cost of these damages is estimated according to Yaacov Gadish (of blessed memory) in the function that is presented below:

Table 6: Shortage and damage

The shortage (mcm ³ /y)	The damage (\$/cm ³)
25	0.58
50	0.81
100	1.02
150	1.09
200	1.17
250	1.47
>250	1.78

Another condition that may cause a significant loss of money to the entrepreneur is a change in the wastewater quality. The quality of the source water is determined according to the quality of the source sewage and the treatment technology. The control over this quality is not absolute, since, both because the sewage characteristics are not homogenous, as well as due to a possible inappropriate treatment plant management. The recycling plant's obligations towards its consumers usually include quality specifications. A sizable deviation from these specifications could cause great damage, and even prevent use of the water.

6. Conclusions

In addition to all health, environmental and economical risks, using treated wastewater in such extended volumes, and investing so many resources in developing and establishing treated wastewater facilities and technologies, pose one more great risk to the State of Israel – a strategic risk.

The water sector reduces the exposure to these risks using the various methods in its possession. "Large projects" are established by Mekorot. The arrangement of costs between the company and the State insures the company against failures that are not under its control. That is to say, the State insures the project, and eventually the risks are its responsibility.

The State's participation in the investments, while the project's entrepreneur is only partially involved in the financing, enables the entrepreneur to create a premium as part of its income, to cover those risks that are not under its control.

The dependency of Israel's agriculture on the wastewater treatment system exposes it to a risk at national level. Agriculture using natural water has been widely practiced for thousands of years, everywhere in the world, and it poses legitimate and known risks. Israel is a pioneer at a global level in recycled treated wastewater irrigation. If an essential problem will appear, environmental, public health or regulative, that will prevent the use of the recycled wastewater, the potential damage could be enormous.

However, when making such an analysis, one must consider the cost of avoiding the development of a treated wastewater supply project. In Israel, we are taking the risk because we are convinced that this cost is much higher. One should keep in mind that the alternatives are either seawater desalinated water supply, or decreased irrigated agricultural areas. Both are unfavorable.

References

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