Chapter 14

Management of transboundary wastewater discharges

Wastewater management in urban communities along the Israeli-Palestinian "border"

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ISRAEL'S EXPERIENCE WITH WASTEWATER REUSE: RELATED ENVIRONMENTAL ISSUES

Israel recycles over eighty percent of its sewage and the treated effluents provide local agriculture with over half of its water supply. This is the result of a consistent national policy that was initiated in the 1950s and which remains unprecedented internationally. Some jurisdictions such as Spain and South Australia have begun to expand their utilization wastewater relatively recently, but at present still recycle less than a quarter of the domestic sewage produced.

The scope of Israel's effluent recycling is generally hailed as a notable environmental achievement. In a region of water scarcity, presumably wastewater reuse both solved the sanitation/health conundrum posed by mounting municipal sewage collection and allowed for a steady growth in agricultural yields, not withstanding the climate-change induced drop in precipitation and relentless growth in population. When initial studies were conducted to evaluate the health impact, there were no signs that wastewater reuse posed any problems to either local human health, hydrology. (Fattal, 1981) It seemed like a classic "win-win-win" technological triumph.

But some twenty years ago the first signs of trouble began to surface. A number of indicators and studies suggested that all was not well in the land of milk, honey and recycled effluents and the unforgiving law of "unintended ecological consequences" had begun to set in.

This chapter considers Israel's experience in wastewater reuse. It begins with a brief review of the incipient stages of wastewater treatment and recycling during the 1950s along with the initial standards and regulatory framework for reducing its environmental impacts. It then considers a series of studies and findings that over time identified numerous problematic implications associated with Israel's aggressive sewage recycling program. It concludes with a summary of recent wastewater treatment standards, remainng policy challenges for overcoming water reuse and suggestions for future research in the field.

Because of its small size and long-term, ambitious efforts in wastewater management, Israel's experience is unique. Present local conditions can be seen as a "fast forward" of the hydrological reality that other countries and regions who today are pursuing similar paths may soon face. As such, the Israeli wastewater reuse story is one that needs to be told and considered internationally.

THE MIXED BLESSINGS OF WASTEWATER REUSE

As the young state of Israel sought to expand agriculture dramatically, despite its modest natural rainfall, a variety of new water sources were considered. Clouds were seeded (Gabbay, 1994), desalination was assessed and water imports contemplated. None offered a sufficiently meaningful, reliable or cost-effective solution. Sewage, on the other hand was a far more promising source of water.

Officials at Israel's Ministry of Health probably deserve most of the credit for Israel's decision to transform sewage from a health hazard into a valuable natural resource. When Israel was established, central sewage systems were rare; even urban areas primarily relied on septic tanks and localized treatment schemes (Tal, 2001). This trend continued for the initial period of statehood when only one wastewater facility was constructed in the first thirty new urban settlements established (Marinov, 1993). But as the population grew and the carrying capacity proved inadequate to absorb the increasing quantities of sewage discharges, Israel's sanitation problem spilled out into the public realm: streams became putrid, mosquito infestation was unbearable, beaches were closed, drinking water frequently suffered from bacterial contamination and associated disease outbreaks were not infrequent (Shuval, 1967). In 1958, the Ministry of Health began requiring chlorination of drinking water, but this did not get at the root of the growing sewage problem.

Aaron Amrami, director of the Ministry's sanitation department during the 1950s found willing partners among Israel's farmers. Many farming communities had already set up small, ad hoc wastewater irrigation projects in order to overcome their limited water allocations or access to water sources (Shuval, 1980). Farmers also saw benefits associated with potentially reduced fertilizer requirements, due to the high levels of nutrients in the irrigation waters (Avnimelech, 1993). Most of all, they couldn't argue with the significantly higher yields found in fields irrigated with effluents (Shuval, 1962). So they grew used to the smell and embraced the new source of irrigation water.

By 1956, a National Masterplan was put forward for irrigation by TAHAL, the recently formed agency for water planning. It called for 150 million cubic meters of wastewater for reuse in Israel (Wachs, 1971). The plan was soon put into action: by 1962 over 50 projects brought treated effluent from Israeli cities to the nation's farms. Within a decade the number had more than doubled so that by 1972, 20% of urban sewage was recycled (Tal, 2002). In 1972, based on a World Bank grant, Israel began to build a major, regional treatment facility for the greater Tel Aviv "Dan Association of Cities". The wastewater from Israel's largest urban area was soon entirely recycled after being injected into an aquifer for temporary filtration and soil aquifer treatment (SAT).

By the mid-1970s, Israel could already boast the world's most sophisticated and ambitious program. Given, Israel's asymmetrical seasonal rainfall, storage capacity proved to be a problem. During the 1990s, the Jewish National Fund, a public corporation spent hundreds of millions of dollars in establishing a broad, national network of over a one hundred reservoirs to hold the effluents during the rainy season to allow for optimal distribution (Tal, 2006). As the years went on, the percentage of sewage recycled steadily grew. In 2009, the total amount of wastewater recycled nationally reached over 500 million cubic meters – more than three times the projections of the original Tahal Plan, with 100% reuse objectives no longer sounding delusional (Israel Ministry of Environment, 2009).

Water managers at the Ministry of Health were hardly unaware of effluent recycling's potential health impacts. As early as 1953, bacteria and pathogens, along with the high salinity concentrations, were the target of the world's first recommended wastewater reuse standards. (Shuval, 1962-b). Cognizant of the enormous gap between the standards and the actual levels of treatment available – which at the time were limited to primary treatment (separation), Ministry of Health regulators recommended limitations on the kinds of crops that could be used: effluents was only to provide irrigation for cotton, fodder and produce that was not consumed raw. During the 1970s, a Hebrew University team undertook an epidemiological study among 81 agricultural communities that utilized wastewater and were quick to declare effluent irrigation to be perfectly safe. (Fattal, 1981). In retrospect, the celebration was premature.

ENVIRONMENTAL CONSEQUENCES OF WASTEWATER REUSE

Israel's great national experiment with wastewater reuse continues to this day, but more soberly. The potential consequences and concerns are increasingly well recognized – even if not fully addressed. Table 1 offers a list of basic environmental problems divided by impact on humans and plants and soils:

Bacteria and pathogens

The most basic environmental health risk associated with wastewater reuse involves the direct exposure of humans to the pathogens and bacteria arising from human excrement. It took many years for Israel to make a transition to irrigation systems

Table 1 Wastewater Reuse: Health, Environmental and Agricultural Impacts.

Public Health/Environmental Hazards
• Pathogens/Bacteria • Organic pollutants • Chlorides • Toxic compounds (heavy metals, organochlorines, etc.) • Endocrine Disruptors (biologically active compounds) • Plants and Soil Hazards High Salinity • Sodification of soil (SAR) • Excess Boron • Excess Nitrogen and Phosphorus

that largely avert these hazards. But before it did, as the systematic dissemination of sewage water grew during the 1960s, gastrointestinal disease expanded accordingly – with 6% of all hospitalizations linked to stomach illnesses. (Cohen, 1971) Vegetables were singled out as the key route of exposure. A major cholera epidemic in Jerusalem in 1970 (Gerichter, 1971) and subsequently in Gaza (Imre, 1971) were perhaps the most widely publicized "downside" of the period's general enthusiasm for irrigation with effluents. After hearings in the Knesset, Israel's Parliament realized the country had a problem and amended the relevant law. The Ministry of Health was empowered to set formal standards for wastewater irrigation. But these were not published until 1981 (Public Health Principles, 1981), and it would take years before compliance levels became acceptable.

Adequacy of wastewater treatment: Today, to a large extent, Israel has succeeded in reducing the acute risks associated with direct exposure of pathogenic and bacterial contaminants in wastewater to the end-users in farm operations. Here drip irrigation has made an important contribution, as it reduces the airborne dissemination of these bacteria through sprinkler systems as was common in the past. Upgraded treatment infrastructure, means that concentrations of bacteria in treated effluents has improved, as have general sanitation and packaging practices for local produce. While general water contamination is beyond the scope of the present discussion, it is worth noting that sewage treatment levels still are often not sufficient to reduce the direct impact on receiving streams and eutrophication along with general contamination of surface waters remain commonplace. (Asaf, 2007).

Wastewater is invariably high in salinity and nutrients. While surely not the sole ground water pollution source, wide spread effluent recycling has contributed to the steady decline in the potability of aquifers, particularly in the sandy aquifer along Israel's coastline. During the early 1990s, the Chief Scientist in the Ministry of the Environment proposed regulations (accompanied by a detailed map identifying sensitive carstic and sandy hydrological zones) where wastewater reuse should be banned. But the Ministry of Agriculture was not supportive and the policy was never implemented. (Tal, 2002), and so the groundwater contamination problem grew worse. Figure 1 shows the historic increase in the aquifer's average concentration of nutrients and salinity.

But conventional pollutants like chlorine and nitrates were only the "tip of the iceberg". By the late 1980s, water quality analysis pointed to the inadequacy of existing sewage recycling practices. Leah Muszkot, an analytical chemist based at the Ministry of Agriculture's Volcani Institute took water samples from wells located beneath fields that had been irrigated with wastewater. Her publications drew attention to high concentrations of industrial solvents whose source could not be traced to the surrounding rural areas, but rather to the wastewater which had been used for irrigation and then percolated into the groundwater below (Muszkat, 1988, Muszkat, 1990, Muszkat, 1993).

Muzkot's findings highlighted the flawed dynamics of local wastewater treatment: regulatory demands for pretreatment among Israeli industrial manufacturers were minimal and even these were poorly enforced. Because of this, municipal waste treatment facilities received sewage with chemicals that conventional primary and secondary processes are unable to break down. None of these were listed among the conventional pollutant standards that wastewater had to meet prior to reycling. As a result, effluent reuse systematically spread high concentrations of industrial chemicals across agricul-

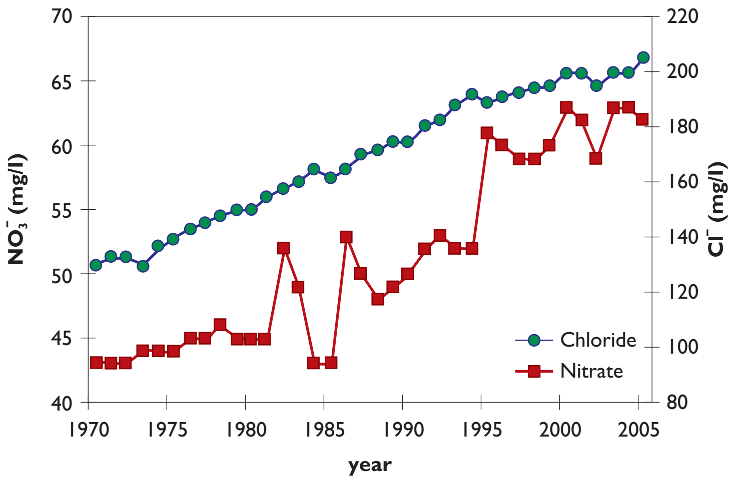

Figure 1 Nitrates and Chlorides Concentrations in the Coastal Aquifer 1970–2005. (*Source*: Israel Hydrological Service.).

tural regions. Eventually these percolated into groundwater, manifested in the presence of measurable levels of toluene, benzene and other substances in well water.

Controlling boron in effluents: Not only were industrial chemical health hazards identified as a problem in Israel's wastewater during this period. Farmers also noticed that many plant leaves were suffering when irrigated with the municipal effluents. Eventually, the damage was associated with high Boron concentrations (Pettygrove, G.S. 1985). Boron at the time was a conventional compound in most household detergents in Israel, and indeed poses no human health concerns. As a result, there were no sewage treatment standards for the element. Recycling, however, changed its harmless status.

While in trace quantities it is an essential mineral for plant growth, when Boron concentrations become too high it can become toxic to leaves. Secondary treatment at wastewater treatment plants reduced organic load and removed most pathogens, but it did not reduce concentrations of boron (Ben-Gal, 2006). Fortunately, this unanticipated environmental side effect of wastewater reuse was easily remedied from a regulatory perspective.

In 1994, the Ministry of Environment enacted new regulations designed to reduce the salinity of sewage. These include limits on ion exchangers, controlling the use of salt in slaughterhouses (in the koshering process), discharge of brine to sewers. But they also included the phase-in of new controls on formulation of domestic and industrial detergents, dramatically reducing allowable boron concentrations in detergents (Weber, 2002). Figure 2 shows the subsequent dramatic drop in Boron concentrations that occured after the policy was implemented in 1999.

The salinity conundrum: Professor Dan Zaslavsky is an unlikely environmental campaigner and zealous advocate for reforming Israel's present dependence on effluent irrigation. As a former chief scientist at the Ministry of Energy and later,

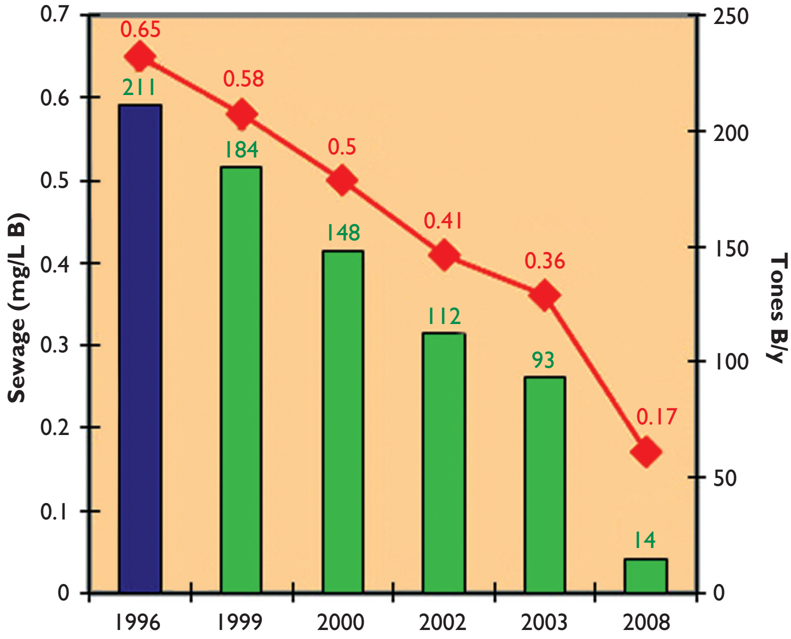

Figure 2 Impact of New Israel Standard for Boron in detergents, on water. (*Source*: Israel Ministry of Environmental Protection).

National Water Commissioner, he was ostensibly the "consummate establishment" inside expert. But his professional background and areas of interest are far more diverse than a typical civil engineering professor and the steady decline in water quality gave him no rest. When Zaslavksy began to speak out vociferously about what he viewed as the folly of public policies in wastewater management, it resonated far more than the usual green critique.

Zaslvasky's traced the country's present orientation on the subject to 1978 when Israel signed the UN sponsored "Barcelona Convention for Protection of the Mediterranean Sea". Among the convention protocols was a strict prohibition on discharge of wastewater into the Sea. The logical corollary was development of a default bias towards land based disposal for wastewater. Zaslavsky argued that the ill-considered, national obsession with effluent irrigation was born of this dynamic (Zaslavksy, 2004).

As a soil physics expert, Zaslavksy reckoned that the environmental price of embracing effluent irrigation was far greater – and more irreversible than had previously acknowledged. Beyond the direct damage to plants from the salty waters and soils, the sodium compounds catalyzed ion exchange in the clay fraction of the soil leaving it permanently changed. The dispersion of the wastewater clogged the ground and stymied aeration, with the resulting surface crust damaging seed sprouting, soil aeration and irrigation. He also assailed the ubiquitous coli bacteria, that could be found more or less, wherever recycled wastewater was found in the irrigation stream.

Diseases and micro-organisms in the water, Zaslavsky argued, pass from the soil to the roots through plant stems all the way to the fruit. Salmonella was an example of one such biological contaminant. Moreover, he argued that the holding reservoirs bred mosquitoes, increasing the risk of West Nile fever.

Professor Zaslvasky built his arguments beyond hydrology, and included an economic price tag for what he believed to be fool-hardy public policy. Wastewater storage for summer use led to a 20% loss of water to evaporation, which constituted a cost. The system also required heavy filtration and chlorination expenses to prevent clogging in the irrigation system. The leaching of salts out of the soil had to be undertaken at increasingly great depths in order to leach effluent salinity out of root zone. Eventually, these solutes would have to be removed from the ground water and this would involve considerable costs – which he estimated would be roughly 70 cents per cubic meter higher than present, narrow market prices. When Zaslvsky crunched the numbers in a full-cost, environmental, accounting, they showed that a cubic meter of sewage (based on 2007 dollars) would be as much as 1.5–2.5 dollars/m^3 – roughly three times the going price for desalinating a comparable quantity of sea water. Effluent irrigation, economically did not seem to make sense.

Endocrine disruptors and antibiotics: Zaslavsky also argued that the constant flow of treated wastewater would lead to hazardous concentrations of biologically active substances in groundwater, but had little data on which to base such assertions. But this would change. In May 2009, a research team at Hadassah Hospital's Medical Center presented alarming figures about the condition of sperm among Israeli males. (Har-Nir, 2009). The group reported that the between the ten-year period between 1994–1999 and 2004–2008, a 40% drop in sperm concentrations could be observed among Israeli donors. (Average sperm dropped from a concentration of 106 ± 25 million spermatozoa/cc with 79% ± 4.5% motility to 67 ± 15 million/cc with 68% ± 4% motile sperm (Haimov-Kochman 2012).) These numbers had very real implications: Some 2/3 s of Israeli males who sought to serve as sperm donors were rejected for not meeting local fertility standards. If present trends continue to 2020 – the average Israeli man would be characterized as being "reproductively impaired" according to present WHO criteria.

While the Hadassah research team could not offer an empirically proven cause for the phenomenon, researchers privately voiced suspicions that the drop was the result of endocrine disrupting chemicals in the water – substances with hormone like properties which they assumed had been transported via irrigated effluents. The effect of endocrine disruptors on a variety of physiological functions had first been brought to world attention in the late 1990s through the publication of the best selling *Our Stolen Future* (Colborn 1997). The authors documented dozens of cases of reproductive and sexual dysfunction in ecological systems exposed to endocrines as well as worrying trends in humans, such as the rise in premature pubescence, that they attributed to this diverse family of endocrine disrupting chemicals. Now, a decade later, a number of water quality experts in Israel informally expressed their intuitive suspicions about the source of the sperm count figures. Wastewater containing residual hormones from the dairy and meat industry, flushed birth control pills and other endocrine disrupting chemicals were starting to wreak havoc on the country's reproductive systems.

Such an assertion found confirmation in the growing list of antibiotics measured in ground water lying below fields with a history of wastewater reuse. For example, Tel Aviv University hydrochemist, Dr. Dror Avisar and his research team. found relatively high concentrations of the antibiotic sulfamethoxazole (SMX) in the water table region, in two monitoring wells. The antibiotics proved to be highly persistent, with detection taking place in the unsaturated zone after a transport period of roughly 16 years. The authors pointed out that more than 90% of the metabolized and unmetabolized excreted antibiotics can be detected in wastewater treatment plants. Even state-of-the-art tertiary treatments for wastewater treatment are not designed to effectively disable their activity. Tracing the biological contaminants to irrigation practices that began in the 1960s, the authors' conclusion was straight forward: recharge of effluents into aquifers and irrigation with sewage effluents over the replenishment area of aquifers leads to groundwater contamination by antibiotics. (Avisar, 2009-a). Other antibiotics and their degradation products were identified in other surveys (Lamm, 2009). The implications for producing new strains of antibiotic resistant bacteria should be of serious concern (Chee-Sanford, 2001).

NEW EFFLUENT REUSE STANDARDS

By the end of the twentieth century it was apparent that Israeli success in reaching such exceptional levels of wastewater reuse had produced environmental problems that needed to be addressed. The existing standards for wastewater treatment were extremely simple and lenient, based on a so-called "20/30" level of treatment (20 mg/l Biochemical Oxygen Demand – BOD; 30 mg/l Total Suspended Solids – TSS) that was no longer appropriate. The required performance standard was roughly analogous to secondary treatment technologies. These were probably sufficient for discharge into European rivers, given the high levels of dilution. (Tal, 2006). But for a country with largely ephemeral streams and ubiquitous wastewater reuse, they were clearly not up to the task. Tightening and expanding the standards, it was thought, would generate effluents that could then be permitted for irrigating any crop. The upgrade it was thought would save scarce fresh water supplies for the growing domestic sector while preserving the extent of crop range currently in cultivation. (Tal, 2005).

An inter-ministerial committee was formed headed by then-Deputy Director of the Ministry of Environment, Yossi Inbar. The negotiations over the standard were protracted but in 2002 a new standard for wastewater reuse was proposed. It was designed to be dichotomous with maximum levels set for irrigation, and a separate standard set for discharge into streams. The irrigation standards were based on considerations of soil, flora, hydrological and public health. Standards for effluents released into stream standards were based on ecological carrying capacity. After considerable debate, in 2005 Israel's government adopted the new treatment guidelines and began the slow process of upgrading sewage infrastructure. (Lawhon, 2006).

The primary objective of the new standards is to allow *all* of the country's treated wastewater to be safely used for unrestricted irrigation, without posing risk to crops, soils or water resources. For example, the standard replaces the 20/30 standard with a 10/10 BOD/TSS requirement. It also contains standards for boron and salinity. Heavy metals are to be removed at the source. Nutrient removal is to increase in areas of hydrological sensitivity. The proposed standard will probably take another ten years to fully phase in, at an estimated expense of 220 million dollars (Israel Ministry of Environment, 2005). Table 2 offers a parameter-specific list of the new standard, divided according to the levels required for "unrestricted irrigation" versus "stream discharges".

Table 2 Proposed maximum levels in effluent reuse for unrestricted irrigation and discharge to rivers.

Parameter	*Unrestricted*	*Streams*	*Parameter*	*Unrestricted*	*Streams*
Conductivity	1.4 dS/m		**Arsenic**	0.1 mg/l	0.1 mg/l
BOD	10 mg/l	10 mg/l	**Barium**		50 mg/l
TSS	10 mg/l	10 mg/l	**Mercury**	0.002 mg/l	0.0005 mg/l
COD	100 mg/l	70 mg/l	**Chromium**	0.1 mg/l	0.05 mg/l
Ammonia	20 mg/l	1.5 mg/l	**Nickel**	0.2 mg/l	0.05 mg/l
Total nitrogen	25 mg/l	10 mg/l	**Selenium**	0.02 mg/l	
Total phosphorus	5 mg/l	1.0 mg/l	**Lead**	0.1 mg/l	0.008 mg/l
Chloride	250 mg/l	400 mg/l	**Cadmium**	0.01 mg/l	0.005 mg/l
Fluoride	2 mg/l		**Zinc**	2 mg/l	0.2 mg/l
Sodium	150 mg/l	200 mg/l	**Iron**	2 mg/l	
Fecal Coliform	10 per 100 ml	200 p 100 ml	**Copper**	0.2 mg/l	0.02 mg/l
Dissolved oxygen	< 0.5 mg/l	< 3 mg/l	**Manganese**	0.2 mg/l	
pH	6.5–8.5	7.0–8.5	**Aluminum**	5 mg/l	
Hydrocarbons		1 mg/l	**Molybdenum**	0.01 mg/l	
Residual chlorine	1 mg/l	0.05 mg/l	**Vanadium**	0.1 mg/l	
Anionic detergent	2 mg/l	0.5 mg/l	**Beryllium**	0.1 mg/l	
Total oil		1 mg/l	**Cobalt**	0.05 mg/l	
SAR	5 mmol/|L 0.5		**Lithium**	2.5 mg/l	
Boron	0.4 mg/l		**Cyanide**	0.1 mg/l	0.005 mg/l

DISCUSSION AND CONCLUSIONS

The sustainability of Israel's present policies regarding wastewater reuse remains a matter of controversy. Many claim that the new, toughened "Inbar" treatment criteria are not sufficient. For example, even if there was full compliance with the standard (which may take decades to attain, if ever) it would still leave the problem of emerging contaminants such as endocrine disruptors, antibiotics and trace metals unaddressed.

Zaslavsky remains highly critical of the new standards, calling for nothing less than pushing sewage through reverse osmosis treatment in order for it to reach drinking water quality. He points to the ultimate contribution of even Inbar-level effluents to the ever worsening soil and water salinity. If municipal effluents were "desalinized", they could be safely added to the reservoir of national water resources without limiting the water's ultimate usage. The estimated 30 cents/ m^3 for treatment, presumably would be more cost-effective than the inordinate expense (and dubious outcome) associated with aquifer restoration once contamination by salinity and other pollutants leads to the decommissioning of wells. The process today is also cheap enough so that most farmers could purchase desalinized effluents at full-price and still make a profit from their produce. But desalinization is not without its own environmental consequences. The expenses (environmental and economic) associated with the higher energy requirements (and green house gases) may not be sufficiently internalized in his calculation, nor the cumulative impact of the brine discharge on marine ecology.

There is no denying that the recent drop in Israel's annual precipitation, coupled with the steady rise in population and living standards, means that water has become scarcer than ever in the Middle East. Given its substantial contribution to the country's hydrological balance, it is hard to imagine Israeli water managers giving up on the prodigious supply of sewage effluents. But, future damages may come to match, or even exceed the past environmental and agricultural price that has been paid for Israel's experiment in effluent irrigation.

Intensified research must provide cost-effective treatment strategies for removing the biologically active compounds in the wastewater. Effluents' inevitably high chloride levels and salinity remain a major threat to long-term agricultural productivity. While drought and salt resistant crops are constantly being developed, at some point, plant scientists will not be able to keep up with the steady degradation in soil and water quality. In short, living in the long-term with sewage recycling will not only demand an investment in treatment infrastructure but also in research. Given Israel's long history of effluent recycling, there is no better place to begin the critical challenge of finding ways to overcome the many obstacles to safe and sustainable wastewater reuse.

REFERENCES

Asaf, L., Negaoker, Neta Tal, A.L. & Jonathan Al Khateeb, N. (2007). "Transboundary Stream Restoration in Israel and the Palestinian Authority", ", Integrated Water Resources Management and Security in the Middle East,(C. Lipchin, E. Pallant, Ed.) Springer, 285–295.

Avisar, D., Lester, Y. & Ronen, D. (2009-a). "Sulfamethoxazole Contamination of a Deep Phreatic Aquifer", *Science of the Total Environment* 407, 4278–4282.

Avisar, D., Levin G. & Gozlan, I. (2009-b). The processes affecting oxytetracycline contamination of groundwater in a phreatic aquifer underlying industrial fish ponds in Israel. *Environmental Earth Sciences* Vol. 59, No. 4, pp. 939–945.

Avnimelech, Y. (1993). "Irrigation with Sewage Effluents: The Israeli Experience," *Environmental Science and Technology,* Vol. 27, No. 7, 1279.

Ben-Gal, A., Tel-Tsur, N. & Tal, A. (2006) "The Sustainability of Arid Agriculture: Trends and Challenges", *Annals of the Arid Zone* 45(2): 1–31.

Chee-Sanford, J.C., Aminov, R.I, Krapac, I.J., Garrigues-Jeanjean, N. & Mackie, R.I. (2001). Occurrence and diversity of tetracycline resistance genes in lagoons and groundwater underlying two swine production facilities. *Applied Environmental Microbiology*, 67(4):1494–502.

Cohen, J., *et. al.* (1971). "The Endemicity of Gastrointestinal Infections," Jerusalem, Ministry of Health, *Public Health,* p. 3.

Colborn, T., Dunamsky, D. & Meyers, J.P. (1997). *Our Stolen Future: Are We Threatening Our Fertility, Intelligence, and Survival? – A Scientific Detective* Story, New York, Penguin.

Fattal, B. & Shuval, H. "Historical Prospective Epidemiological Study of Wastewater Utilization in Kibbutzim in Israel, 1974–77,' *Developments in Arid Zone Ecology and Environmental Quality,* (Ed. Hillel Shuval) Philadelphia, PA. Balaban ISS, 1981, pp. 333–343.

Gabbay, S. *The Environment in Israel*, 1994, Jerusalem, Ministry of Environment, p. 21

Gerichter, B. & Cahan, D. (1971). "Laboratory Investigations During the Cholera Outbreak in Jerusalem and Gaza, 1970, p. 26–35.T.A. Schwartz, "The Jerusalem Cholera Outbreak, The Course of the Epidemiological Investigation, "*Public Health,* 13.

Haimov-Kochman, R., Har-Nir, R., Ein-Mor, E., Ben-Shoshan, V., Greenfield, C., Eldar, I., Bdolah, Y. & Hurwitz, A. (2012). "Is the quality of donated semen deteriorating? Findings from a 15 year longitudinal analysis of weekly sperm samples," *The Israel Medical Association Journal*, 14(6): 372–377.

Har-Nir, R., Ben-Shoshan, V., Greenfield, C., Eldar, I., Bdolah, Y.H. & Arye Haimov-Kochman, R. (2009). "Declining Quality Of Donated Semen – A 10 Years Historical Comparative Cohort" Unpublished manuscript, May 12, 2009.

Imre, Z., *et. al.* (1971). "The Cholera Outbreak With Vibrio Cholerae in the Gaza Area in 1970, *Public Health,* 39–40.

Israel Ministry of the Environment. (2005). *Wastewater treatment plants*. Israel Ministry of Environment website: http://www.sviva.gov.il/

Israel Secondary Regulations 1981, (*Kovetz Takano*t) 1357, 718.

Lamm, A., Mayer, A., Gozlan, I. & Avisar, D. (2009). "Detection of Amoxicillin- Diketopiperazine-2″, 5″ in Wastewater Samples", *Journal of. Environmental. Science and. Health, Part A*. vol.44, No.14. 1512–1514.

Lawhon, P., Schwartz, M. (2006). Linking environmental and economic sustainability in establishing standards for wastewater re-use in Israel, *Water Science Technology* 53(9), 203–212.

Marinov, U. (1993). "How Israel Handles the Environment and Development," *Environmental Science and Technology,* vol. 27, No. 7, 1253.

Muszkat, L., *et al.* (1993). "Penetration of pesticides and industrial organics into the depth of soil and groundwater. Arch Insect" Biochem Physiol 1993; 22:487–99.

Muszkot, L. (1988). "First Results of Research that Examined Ground Water Point to Pollution by Hazardous Organic Materials," *Biosphera,* , October, 15.

Muszkot, L., *et al.* (1990). "Large Scale Contamination of Deep Groundwaters by Organic Pollutants," *Advances in Mass Spectrometry,* 11B, p. 1628.

Pettygrove, G.S. & Asano, T. (1985). *Irrigation with Reclaimed Municipal Wastewater*. Lewis Publishers, Chelsea, Mi. 518Public Health Principles.

Shuval, H. (1962) "Public Health Aspects of Waste Water Utilization in Israel, *Proceedings of the 17th Industrial Wastes Conference,* Purdue University, 651–652.

Shuval, H. (1962b). "Waste Water Utilization in Israel," *Proceedings of an International Seminar on Soil and Water Utilization,* South Dakota, Brookings, 1962, p. 40

Shuval, H. (1980). "Quality Management Aspects of Wastewater Reuse in Israel," *Water Quality Management Under Conditions of Scarcity, Israel as a Case Study,* (Hillel Shuval, Ed.) New York, Academic Press.

Shuval, H. "The Problem of Sewage and Waste Discharges in Israel, " *Lecture to Sanitary Engineers,* February 2, 1967, Tzrifin, Israel.

Tal, A. (2002). *Pollution in a Promised Land – An Environmental History of Israel*, Berkeley, California, University of California Press.

Tal, A. (2006). "Seeking Sustainability: Israel's Evolving Water Management Strategy", *Science,*. 313, August 25, 2006, 1081–1084.

Tal, A. Ben-Gal, A., Lawhon, P. & Rassass, D. (2005). *Sustainable Water Management in the Drylands: Recent Israeli Experience*, Jerusalem, Israel Ministry of Foreign Affairs, October.

Wachs, A. (1971). "The Outlook for Wastewater Utilization in Israel," *Developments in Water Quality Research,* (Shuval Ed.) Ann Arbor Mich. Ann Arbor Science Publishers, 109–111.

Weber, B. & Juanico, M. (2002). "Salt reduction in municipal sewage allocated for reuse: the outcome of a new policy in Israel",. Israel Ministry of Environment website, http://www.sviva.gov.il/Enviroment/Static/Binaries/Articals/baruch_web_1.pdf

Zaslavsky, D., Guhteh, R. & Sahar, A. (2004). *Policies for Utilizing Sewage in Israel – Sewage Treatment for Effluent Irrigation or Desalinating Effluents to Drinking Water Quality,* Haifa, Technion.