Chapter 5

Wastewater

The main potential risk to public health from the use of wastewater for agricultural irrigation is the transport of pathogens to crops through insufficiently treated wastewater. In light of the threat of antibiotic resistance to global health, there is increasing concern regarding the potential role of wastewater treatment plants in the spread of antibiotic resistant genes and bacteria. In addition, there is evidence that crops irrigated with treated wastewater may contain pharmaceuticals and other emerging contaminants of concern. It is still unknown whether exposure to very low levels of pharmaceuticals and other contaminants from consumption of crops irrigated with treated wastewater is associated with adverse health effects.

Israel is a world leader in the reuse of domestic wastewater: more than 80% of wastewater is reused and 50% of wastewater undergoes tertiary treatment (treatment that improves the quality of wastewater to a level that allows for unlimited irrigation)[8].

Policy and Regulations

Current regulations for wastewater quality address the potential public health risk due to pathogen transport, as well as the potential public health and agricultural risks due to the presence of metals in wastewater. The Ministry of Health (MoH) and the Ministry of Environmental Protection (MoEP) are jointly responsible for setting standards for the quality of water used for irrigation. The standards define two types of wastewater used for irrigation:

- Wastewater following secondary treatment, which is used for industrial crops (e.g., cotton and fodder), crops that are dried in the sun for at least 60 days (e.g., corn and wheat), and fruit trees. There are no limitations on the bacterial concentrations in secondary treatment wastewater[5].

- Wastewater following tertiary treatment, which can be used for unlimited irrigation of edible crops. Tertiary wastewater may contain up to 10 fecal coliforms in 100ml effluent. There are also maximum permitted concentrations of chemicals such as nitrogen (up to 35 mg/L) and sodium (200 ppm); and of metals such as mercury (0.005 mg/L), lead (0.25 mg/L), arsenic (0.25 mg/L), and cadmium (0.025 mg/L)[4].

Current policy requires separating the treated wastewater used for irrigation from the irrigated crop. This includes, for example, defining a minimum distance between the effluent and the fruit through drip irrigation, and limitations regarding the time intervals between irrigation and harvesting (drying in the sun for 60 days helps reduce the pathogen load). The specific requirements also depend on the irrigated crop - for example, there are fewer restrictions on wastewater irrigation for produce eaten dried (such as wheat) or produce with a non-edible peel (such as bananas) than for produce eaten fresh with its peel (such as tomatoes)[5].

In Israel, there are currently no regulatory requirements concerning the presence of pharmaceuticals and other contaminants in treated wastewater for crop irrigation. Based on requirements being developed by the MoH, in collaboration with the MoEP and the Water Authority, factories that produce or develop pharmaceuticals must submit a list of all pharmaceuticals and chemicals that are used or produced in the factory so that testing requirements can be designed for each facility. Issuance of the business license for the facility will be contingent upon testing and reporting.

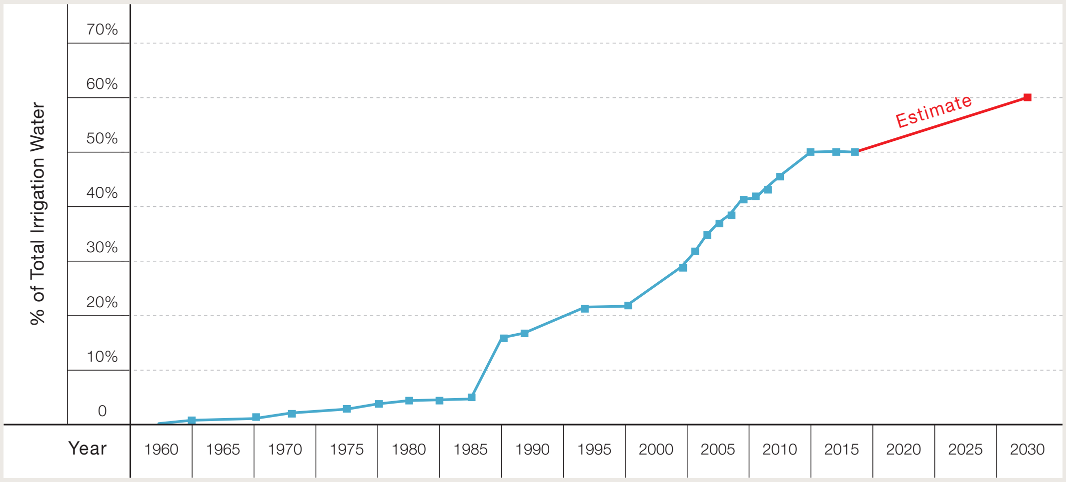
MoEP regulations from 2004 require that sewage sludge from wastewater treatment plants undergo efficient treatment. As of June 2017, the Shafdan Wastewater Treatment Plant (WWTP) is prohibited from disposing sewage sludge into the Mediterranean Sea.

To date, there is no national policy or program to collect household medical waste (including pharmaceuticals) in Israel. An analysis published by the MoH in 2016 indicates that policies for collecting household medical waste exist in many developed countries worldwide. According to data from the Central Bureau of Statistics, only 14% of the public in Israel return household medical waste to pharmacies; most of the public reports tossing unused pharmaceuticals into the trash or toilet at home, which increases the risk that pharmaceuticals will reach wastewater[1,6].

Data on the Use of Treated Wastewater for Irrigation and on Chemicals in Treated Wastewater in Israel

Globally, Israel leads in the reuse of domestic wastewater: more than 80% of wastewater in Israel is reused, compared with less than 10% in the United States. Israel also leads in the use of treated wastewater for agriculture. Currently, 50% of the water used for agricultural irrigation is reclaimed wastewater[8]. This percentage is expected to increase to 60% by 2030 (Figure 1). Israel produces 530 million cubic meters of wastewater every year, most of which is used for agriculture.

Irrigation with Treated Wastewater in Israel
(Percent of Total Water Used for Irrigation), 1960-2030

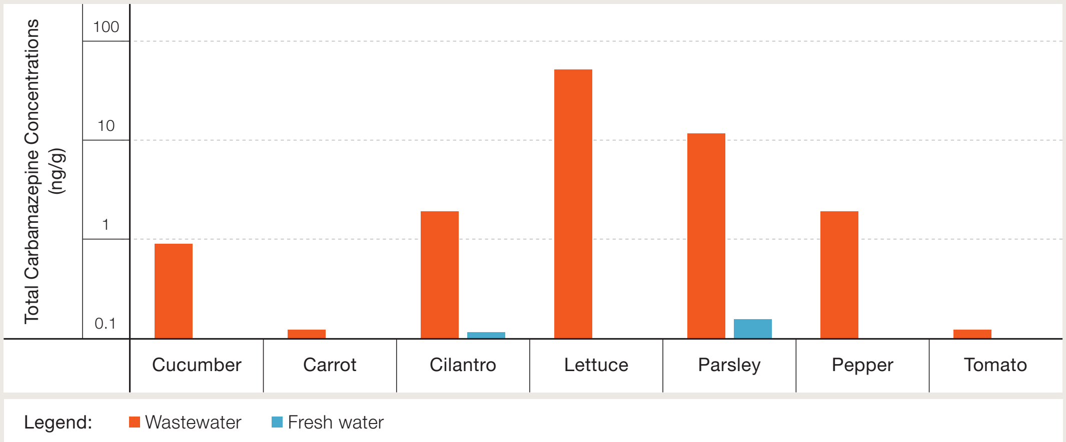


← **Figure 1** Source: Israel Water Authority[7]

Research on Chemicals in Wastewater and on Crops Irrigated with Treated Wastewater

Researchers from the Hebrew University's Center of Excellence in Agriculture and Environmental Health quantified the uptake of pharmaceutical compounds by carrots and sweet potatoes irrigated with treated wastewater and grown in controlled conditions. In both crops, the researchers found traces of the anti-epileptic drugs carbamazepine (CBZ) and lamotrigine, and of caffeine, with higher levels in the leaves than in the roots[9]. This team of researchers also found that CBZ levels were significantly higher in vegetables irrigated with treated wastewater, compared with those irrigated with freshwater (Figure 2)[10].

Concentrations of CBZ and its Metabolites in Agricultural Crops Irrigated with Treated Wastewater versus Freshwater



← **Figure 2** Source: Paltiel et al., 2016[10]

Using a new analytical technique to quantify traces of CBZ and its metabolites in urine, the same team of researchers showed that individuals consuming treated wastewater-irrigated produce excreted CBZ and its metabolites in their urine, while subjects consuming freshwater-irrigated produce excreted undetectable or significantly lower levels of CBZ and its metabolites. The researchers quantified CBZ and its metabolite levels in two groups: Group A received produce irrigated with treated wastewater, and seven days later received freshwater-irrigated produce; Group B received freshwater-irrigated produce and seven days later received produce purchased from a local supermarket; the irrigation sources for the latter were unknown but probably included treated wastewater. The levels of CBZ and its metabolites measured in Group A after consuming the treated wastewater-irrigated produce were high, but these levels significantly decreased after consuming freshwater-irrigated produce. On the other hand, in the control group (Group B), the levels of CBZ and its metabolites were stable (Figure 3)[10].

Concentrations of CBZ and its Metabolites (ng/L) in Urine of Volunteers who Consumed Treated Wastewater-Irrigated Produce Followed by Freshwater-Irrigated Produce (Group A) Versus Concentrations in Urine of Volunteers who Consumed Freshwater-Irrigated Produce Followed by Produce Irrigated from an Unknown Source (Group B)

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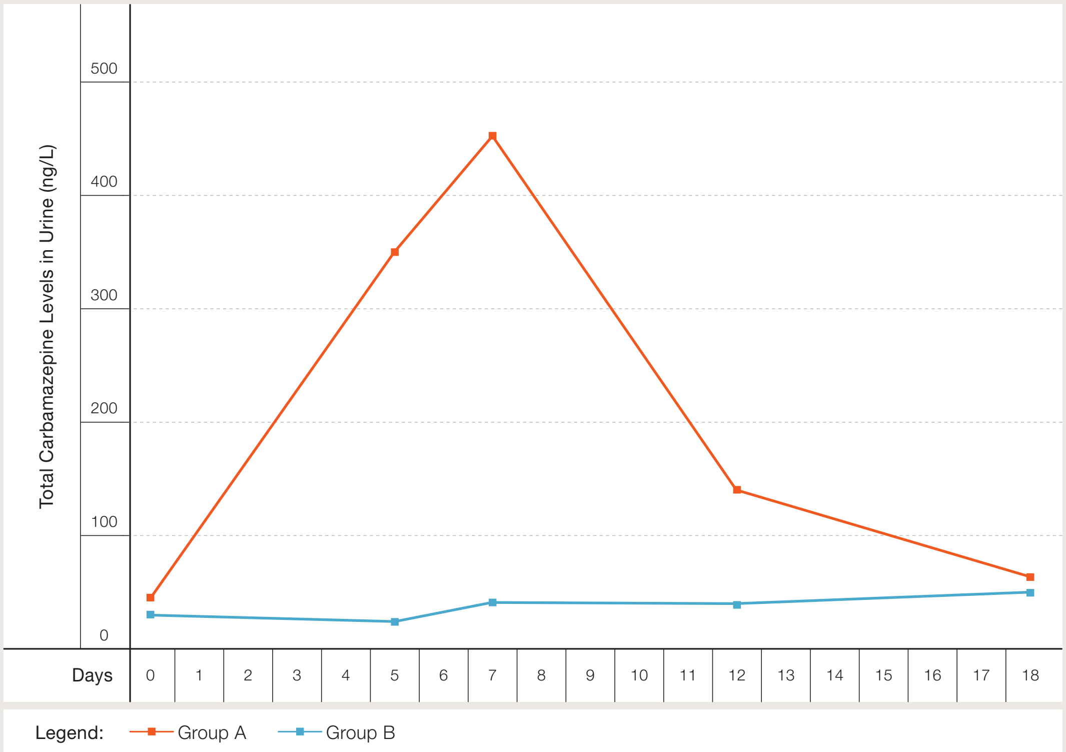
Figure 3
Source:
Paltiel et al., 2016[10]



This team of researchers is now extending the study to examine CBZ levels in urine of healthy Israelis consuming their usual diet, in order to assess CBZ exposure in sub-populations including children, vegetarians, pregnant women, and the elderly.

Researchers at Ben-Gurion University (BGU) and the MoH analyzed the impact of wastewater and floods on water quality and the health of fish in a water reservoir. The researchers examined the levels of nutrients and organic micro-pollutants (OMPs) during 2013-2014 in the Yeruham Lake, and the OMP levels in sediment and fish tissues. The researchers found low concentrations of four OMPs (estrone, CBZ, diclofenac, and bezafibrate) in the lake. Polychlorinated biphenyls (PCBs) and dioxins were found in fish muscle and liver at very low concentrations. Histopathological analysis of the fish in the lake showed they were healthy(12).

A joint study by Israeli researchers from BGU and the MoH, and Palestinian researchers from the Water and Environmental Development Organization (WEDO) and the Water and Soil Environmental Research Unit (WSERU) at Bethlehem University examined the presence of endocrine-disrupting chemicals (EDCs) in Israeli and Palestinian wastewater treatment plants. It should be noted that only secondary treatment is performed at wastewater treatment plants in the Palestinian Authority. The researchers analyzed wastewater, treated wastewater, and sludge in six wastewater treatment plants in Israel and in Palestinian plants. Lower concentrations of bisphenol A (BPA), octylphenol, and triclosan were found in the wastewater in the Palestinian wastewater treatment plants. However, hormone concentrations in wastewater were higher in the Palestinian Authority than in Israel. Removal efficiency in all advanced wastewater treatment plants was high in comparison with averages reported in the world(2).

Researchers from the MoH and the Agricultural Research Organization's Volcani Center are participating in research projects funded by the European Union: the ANSWER (ANtibioticS and mobile resistance elements in WastEwater Reuse applications) project and the NEREUS (New and Emerging Challenges and Opportunities in Wastewater Reuse) project(3).

Progress and Challenges

There has been progress in advancing policy to reduce discharge of pharmaceuticals from pharmaceutical factories into sewage. In addition, the MoH is making efforts to raise public awareness regarding safe disposal of household medical waste(6).

Researchers in Israel have made significant progress in recent years in studying the potential exposure of the population to pharmaceuticals and other contaminants via crops irrigated with treated wastewater, and in understanding the role of wastewater treatment plants in the dissemination of antibiotic-resistant genes. The participation of Israeli researchers in several EU-funded projects, including a survey of antibiotic-resistant bacteria in 30 wastewater treatment plants worldwide, is noteworthy.

There is a need for further research on these emerging issues and a need for continued collaboration and communication between researchers and policy makers.

In 2016, two seminars were conducted with the participation of experts from academia and government officials:

1. An expert consultation on resistance to antibiotics in wastewater included experts from academia, MoH, MoEP, Ministry of Agriculture and Rural Development (MoAg), industry, and additional consultants. The experts concluded that although wastewater may contain antibiotic-resistant bacteria and genes for antibiotic resistance, the current levels of knowledge, science, and experience are insufficient to determine whether antibiotic-resistant bacteria and genes for resistance found in wastewater pose a health risk. The experts recommended:
   (a) "Waste minimization" - decreasing the use of antibiotics by the public and in livestock; and
   (b) Conducting additional research, monitoring, and data collection on resistant bacteria, and antibiotic resistant genes in sewage, wastewater, fields, and agricultural crops, as well as in the population and in hospitals[11].
2. A seminar on micro-pollutants in wastewater and sludge included experts from academia and government (MoH, MoEP, MoAg and the Water Authority). The participants decided to assess the existing knowledge in this field in Israel and in the world in order to re-evaluate policy in this field.

Additional challenges

- Risk assessments need to be performed on the effects of chemical contaminants in treated wastewater, with emphasis on humans, farm animals, and their products (eggs, milk and meat).
- An integrated database should be created that includes chemical and microbiological monitoring of sewage originating in households, hospitals, farms, and the pharmaceuticals and chemical industries; monitoring wastewater treatment plants (before and after treatment); antibiotic resistance in wastewater, soil, plants and crops; and data on specific types of resistant microbes found in hospitals and farms.
- Additional research is needed on more efficient technologies for coping with micro-pollutants and antibiotic resistance in wastewater.

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