Universität für Bodenkultur Wien
University of Natural Resources and Life Sciences, Vienna

Paper within the framework of the lecture Environmental Risk Analysis and Management

Irrigation with treated waste water and potential health risks

Practices and Studies in Israel

written by

Nicola Ines Maria STANY

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Lecture & Task by: Em.O.Univ.Prof. Dipl.-Ing. Dr. Hans Peter NACHTNEBEL
H81600 Institute of Hydrology and Water Management (HyWa)

Affidavit

I hereby declare that I am the sole author of this work. No assistance other than that which is permitted has been used. Ideas and quotes taken directly or indirectly from other sources are identified as such. This written work has not yet been submitted in any part.

Vienna, 05.05.2023 Nicola STANY (eigenhändig)

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Definition of objective and tasks

The paper deals with the challenges and potential health risks of irrigation with treated wastewater (TW) for human health. Irrigation is addressed in the United Nations Sustainable Development Goals (SDGs), due to, among other things, its high environmental impact. Water is furthermore one of the most important and live-allowing natural resources on earth, making growth in human population possible. This paper examines the relationship between TW irrigation and health risk by referencing Israels practices and studies on health impacts. In order to carry out a well-founded analysis and to process the topic in an understandable way, scientific sources such as online journals and books are used to create the work. The need of irrigation and water rises worldwide due to climate change, draughts and an increasing need of resources for a growing population. Israel has been chosen as an example due to its TW irrigation for many years and many scientific researches on the subject, some of which are presented as examples. The aim of the work is to explain the relevance and necessity of careful and thorough regulations and assessments for the use of reclaimed waste water irrigation, having a potential impact on human health and the environment.

Keywords: irrigation, risk, Israel, water resource, treated waste water, sustainable development

1. Introduction

Irrigation with treated wastewater (TW or sometimes also TWW) is gaining importance as an alternative water resource in agricultural practices (Fao 2017). With growing global water scarcity and increasing demand for food, the use of TW to irrigate agricultural land is a promising solution. However, this practice also raises questions regarding potential impacts on human health.

The use of treated wastewater for irrigation can lead to potential risks, especially if the wastewater has not been adequately treated or if certain contaminants are present in the wastewater. It is known that wastewater can contain a variety of chemical compounds and biological pathogens that can cause health effects if they come into contact with food or the human body.

The potential human health effects of TW irrigation range from acute illnesses such as diarrhea and gastrointestinal infections to long-term effects due to exposure to potentially harmful chemicals or the build-up of resistances. Particular attention is being paid to the potential contamination of crops that could absorb contaminants (like Carbamazepine) ingested through TW irrigation and pass them on to the food chain.

To evaluate and minimize the potential health risks associated with TW irrigation, a comprehensive health risk assessment is needed. This includes analysis of treated effluent quality, identification of potential contaminants, assessment of exposure pathways and routes, and estimation of toxicological effects on humans.

The objective of this work is to examine the status quo in Austria and Israel as well as the growing importance of treated wastewater irrigation in agricultural practice and to analyze the potential human health effects as part of a comprehensive health risk assessment. Current knowledge as well as challenges and potential solutions for safe and sustainable TWW irrigation are discussed.
In the course of this work, the current practices with TW irrigation are first presented. Subsequently, this paper addresses the following questions and answers them in the discussion:

Why are studies on irrigation with treated wastewater (TW) and their possible impacts on health relevant?

What are examples of contaminating substances that are passed on via TW irrigation?

What can be done in order to prevent health risks of TW irrigation?

2. Methodology

This paper was prepared with the help of a literature review. This work is based primarily on digital materials, such as scientific journals and articles. Both quantitative and qualitative data were used to answer the research questions.

"BOKU LIT-Search", "Science Direct" and "Google Scholar", among others, served as search engines for the systematic literature search. Search terms used included "irrigation with treated wastewater", "health risk assessment" and "health impacts of TW", with some of these terms also translated from English into German during the search in order to find more material.

This led to relevant scientific information needed to answer the three questions and write the paper. First, a systematic search was started using the "top down" method of terms; the material found as a result subsequently enabled further literature to be obtained by applying a "snowball system". In addition, scientific papers, studies as well as technical literature and sources from the Internet were consulted for an extended literature search. However, only materials with reliable sources and literature citations, which were carefully located and indicated, were chosen to be relevant.

In order to answer the proposed questions in the paper, publications were consulted that relate to health-relevant impacts of agriculture with TW. Due to the literature research and information especially from a course on innovative solutions for dwindling water resources in Rehovot, Israel at the Hebrew University of Jerusalem, the challenges of TW irrigation and possible health risks were able to be well analyzed.

3. Irrigation with treated wastewater (TW)

TW or reclaimed wastewater (RW) is sewage water that has been treated in multiple steps in order to have use for irrigation. The processes that are used depend on the type of wastewater and the desired end use. Generally, the treatment process involves sedimentation, filtration, and disinfection. Contaminants that are removed during the treatment process include organic matter, suspended solids, pathogens, heavy metals, nutrients, and other pollutants (Ofori et al. 2021). TW is one of the most important alternative water resources in arid regions where scarcity of freshwater is common (Chen et al. 2017).

In Israel, a significant amount of irrigation takes place with treated wastewater. The regulatory framework is primarily governed by the Water Authority and the Ministry of Health. Due to limited natural water resources and water scarcity challenges, Israel has invested heavily in the development of water reuse technologies in recent decades. The country has become a global pioneer in irrigation with treated wastewater. About 85% of treated wastewater in Israel is reused for agricultural purposes, but agriculture is also worldwide the biggest demander of water, approximately 80% of the global freshwater (Hashem und Qi 2021). This high percentage is due to advanced wastewater treatment facilities and an extensive network of pipelines to distribute treated wastewater. Treated wastewater is used intensively for crop irrigation, particularly in agricultural regions such as the Jordan Valley and the Negev Desert. Irrigation with treated wastewater in Israel has numerous benefits, including conserving limited natural water resources, ensuring a stable water supply for agriculture, and promoting agricultural production in arid areas. However, there are also challenges related to the quality of treated wastewater, monitoring of irrigation practices, and potential exposure of people and the environment to pollutants. Overall, it can be concluded that Israel serves as a model for other countries facing similar water scarcity issues due to its advanced technologies and comprehensive approach to water reuse. Irrigation with treated wastewater plays an important role in sustainable water use and agriculture in Israel (Berger und Kiperwas 2019).

Compared to Israel, and China, which is considered the biggest global producer and user of wastewater, Austria, with abundant natural water resources, uses little to no treated wastewater for irrigation in agriculture. But the last summers in Austria also showed that the pressure on available water resources is increasing due to climate change. The combination of long dry phases and heavy rainfall events requires a long-term adaptation of urban water management (ÖWAV 2023). The “Österreichischer Wasser- und Abfallwirtschaftsverband” (ÖWAV) therefore for example had a seminar with the TU Vienna in February 2023 about the reuse of treated wastewater. After contacting a participant during the seminar, asking about Austrias regulations on TW irrigation, more information could be gained. DI. Dr. Andrea Bichler from the Federal Ministry Republic of Austria Agriculture Forestry Regions and Water Management explained, that currently, in Austria, the reuse of treated wastewater for agricultural irrigation is generally allowed but requires a water permit. Only one wastewater treatment plant in Austria is known to provide treated wastewater for irrigation, while all other plants discharge solely into water bodies. In some cases, the treated wastewater is infiltrated into the groundwater, mainly for small plants located in isolated areas where there is no nearby water body available.

Starting from June 2023, the EU Regulation on Water Reuse will come into effect in all member states. Austria will utilize the "opt-out" provision and will not (yet) allow water reuse. Therefore, from June 2023 onwards, irrigation with treated wastewater will no longer be permitted in Austria, except for certain conditions such as research or pilot projects.

Irrigation with treated wastewater in Austria is under strict control and carried out in accordance with Austrian environmental and health standards. There are clear guidelines and regulations for the quality of treated wastewater, monitoring of irrigation practices, and protection of the environment and human health (Federal Ministry Republic of Austria Agriculture Forestry Regions and Water Management). Due to the comparably high amount of available freshwater in Austria, this paper focusses more on health impact studies of TW irrigation from Israel and China. The following graphs are from a study on “Environmental Assessment of Wastewater Treatment and Reuse for Irrigation” in 2022 and illustrate the rise in studies on TW and within studies on its irrigation (Mehmeti und Canaj 2022).

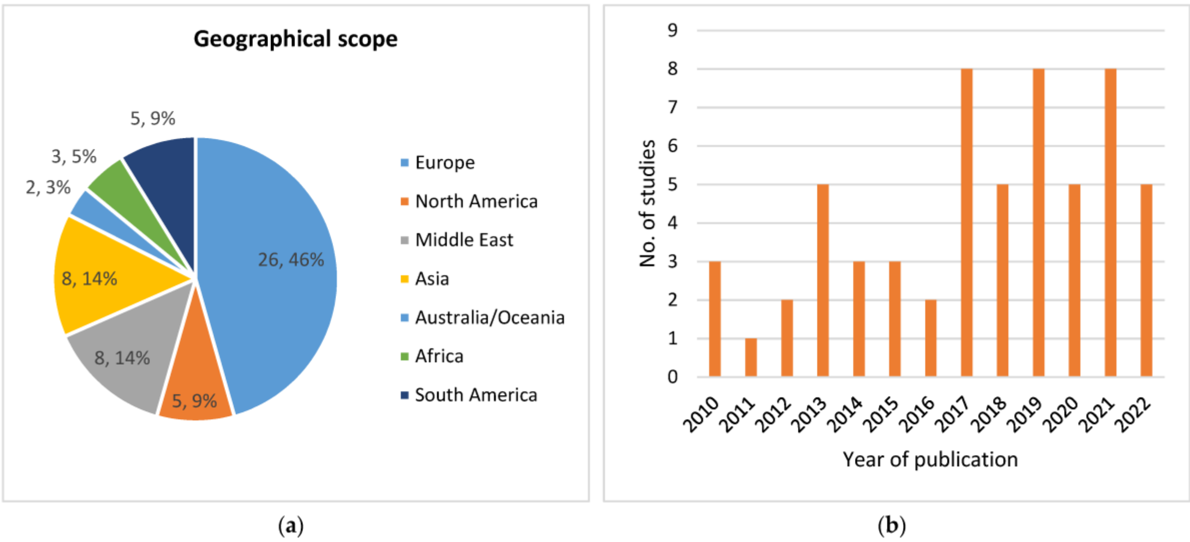

Figure 1: Geographical scope (a) and year of publication (b) of LCA studies on wastewater treatment and reuse including irrigation as a process or scenario (Mehmeti und Canaj 2022)

4. The complexity of treating wastewater for agricultural use

Due to chemically stable components in human medicine and cleaning products for example, the treatment of wastewater is highly complex and it is often not completely possible to clean the water fully from certain substances. Furthermore, agricultural crops are highly sensitive and possibly uptake and accumulate stable substances that are then consumed by humans or leading to negative impacts on crop growth productivity (Christou u. a. 2017). Boron in detergents and the medicine carbamazepine will be examples regarding that matter:

4.1 Boron in laundry detergents

Before TW in Israel is used in agriculture, it undergoes field studies of more than ten years in order to prevent long-term harms that could be undetected in the first years of irrigation (Berger und Kiperwas 2019). The scientific article on boron removal from water and wastewater by Kluczka et al. 2015 writes:

> „Boron is very important micronutrient for the plants, however, it is essential only in small quantities, and its excessive concentrations are damaging and even lethal to plants. In humans, small amounts of boron occur in all tissues. An excess of boron may lead to damage of the nervous system. Therefore, boron concentration in water and wastewater is regulated in many countries.“(Kluczka u. a. 2015).

Due to usage of boron as laundry detergent in common and private households in Israel, the wastewater contained 80-90% of the chemical due to that usage (Berger 2019). The removal of boron in order to irrigate with the contaminated wastewater is expensive and complex and already small amounts have negative impacts on crop production (Kluczka u. a. 2015). The test fields that were irrigated by TW with boron residue showed negative effects on the crops only after several years of irrigation (intense leaf reduction, eventual death of the plants). The state of Israel therefore implemented a new Israeli Standard (IS438) of boron in detergents since 1998 and the amount of chemical residue in wastewater was drastically reduced, as visible in the figure 1 below.

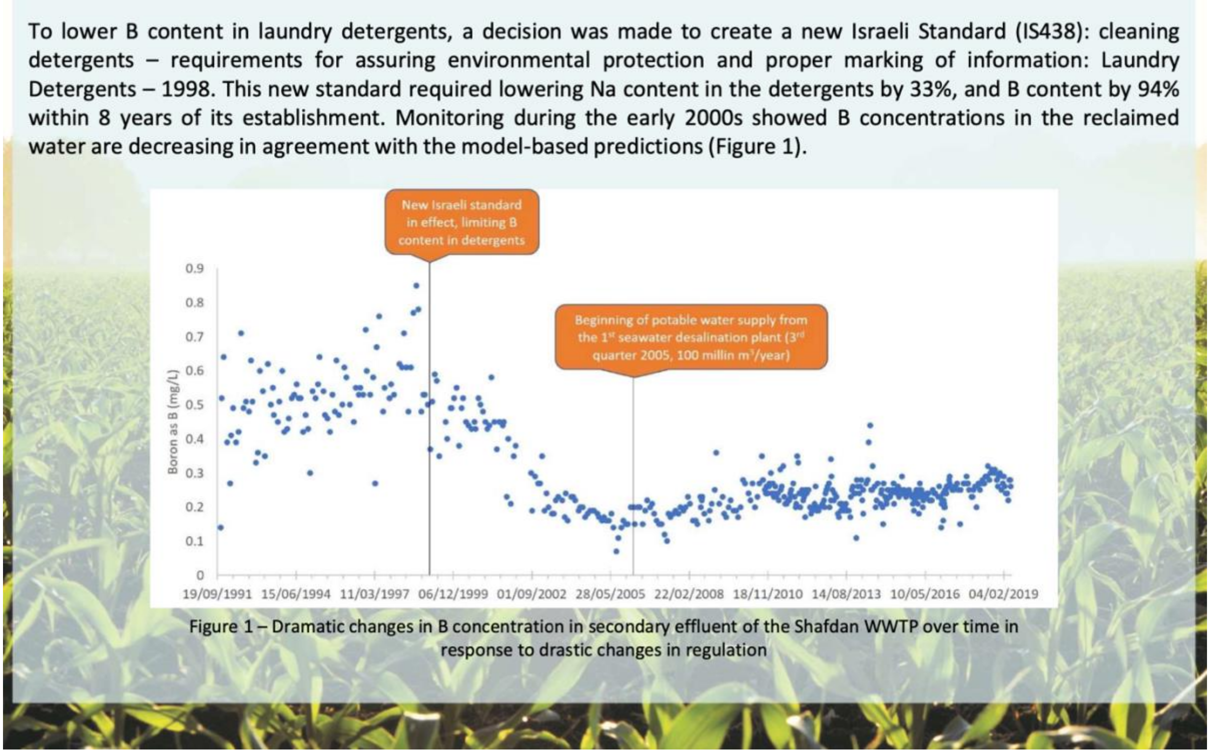
To lower B content in laundry detergents, a decision was made to create a new Israeli Standard (IS438): cleaning detergents – requirements for assuring environmental protection and proper marking of information: Laundry Detergents – 1998. This new standard required lowering Na content in the detergents by 33%, and B content by 94% within 8 years of its establishment. Monitoring during the early 2000s showed B concentrations in the reclaimed water are decreasing in agreement with the model-based predictions (Figure 1).

Figure 1 – Dramatic changes in B concentration in secondary effluent of the Shafdan WWTP over time in response to drastic changes in regulation

Figure 2: Boron concentration regulation 1998 (Berger und Kiperwas 2019)

The new standard turned out to be an effective management for future TW irrigation and raised the importance of long-term studies as well as sustainable product use for a circular system- sustainably degradable detergent use- less contaminated waste water- cleaner TW (Berger und Kiperwas 2019).

4.2 Involuntary exposure of Carbamazepine on humans

Carbamazepine is a pharmaceutical compound commonly used as a mood stabilizer for treatments such as epilepsy, bipolar disorder and certain types of neuropathic pain. When carbamazepine is ingested, it undergoes various metabolic processes in the body and is ultimately excreted in the urine (Kråkström u. a. 2020). Due to its chemical stability, it stays in the environment and the detection of carbamazepine in urine samples indicates recent or continued use of the drug by individuals (Schapira u. a. 2020).

Carbamazepine is one of the most commonly detected pharmaceuticals in TW, this is due to the uptake and accumulation in TW irrigated crops and therefore human consumption of the medicine and infiltration into the wastewater via urination. In a study by Schapira et al., it was found that the concentration of carbamazepine in the urine of healthy people who consumed products that were irrigated with TW was higher than in those irrigated with freshwater (Schapira u. a. 2020).

In the context of domestic wastewater irrigation, carbamazepine can enter the wastewater stream through a variety of routes, including disposal of unused drugs, excretion by individuals taking carbamazepine, and incomplete removal during wastewater treatment processes. Therefore, traces of carbamazepine can be present in treated wastewater, which then is irrigated (Andreozzi u. a. 2002).

When people consume products irrigated with treated wastewater containing carbamazepine, the presence of this compound in their urine is possible and has been studied by Schapira et al. at the Hebrew University of Jerusalem. Plants uptake and accumulate carbamazepine from the TW as they grow, which is then going into the human system by consuming these products. Monitoring of carbamazepine in urine samples provides an indicator of exposure to the compound and can be used to assess potential health risks associated with TW irrigation.

Due to physicality, leaves contain higher amounts of compounds and pesticides than roots, therefore fresh leaves (salads) and fruits have a higher concentration of chemical compounds including carbamazepine, which was also detectable in multiple studies (Mascellani u. a. 2023).

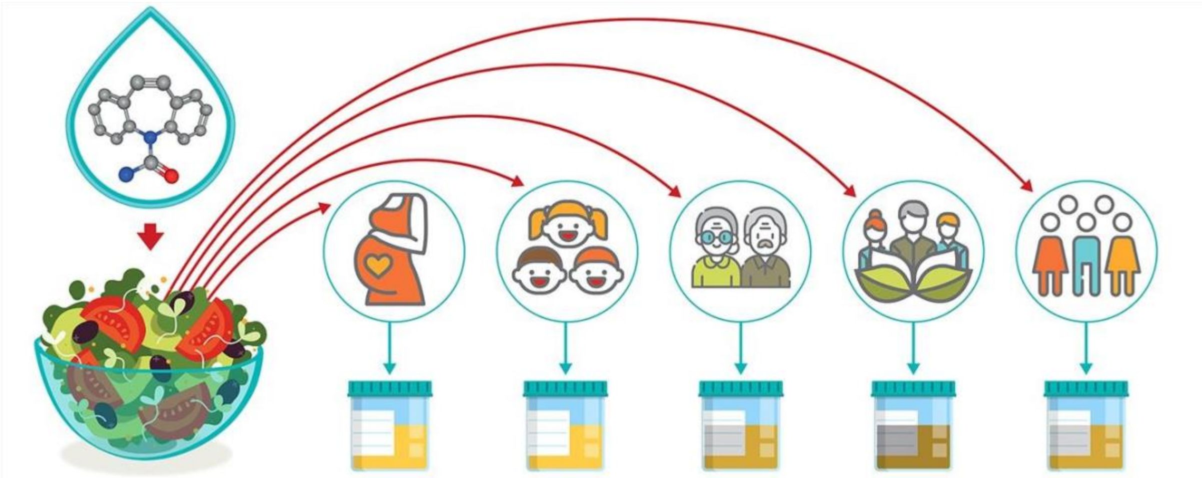

Figure 3: Graphical abstract of the study "Involuntary human exposure to carbamazepine" by (Schapira u. a. 2020)

In the study of Schapira et al. 245 volunteers were examined and around 75% of adults and roughly 20% of children had detectable levels (LOD) of carbamazepine in urine probes after consuming TW irrigated products (Schapira u. a. 2020). The figure 4 has been taken out of the study and illustrates distributions.

M. Schapira, et al.

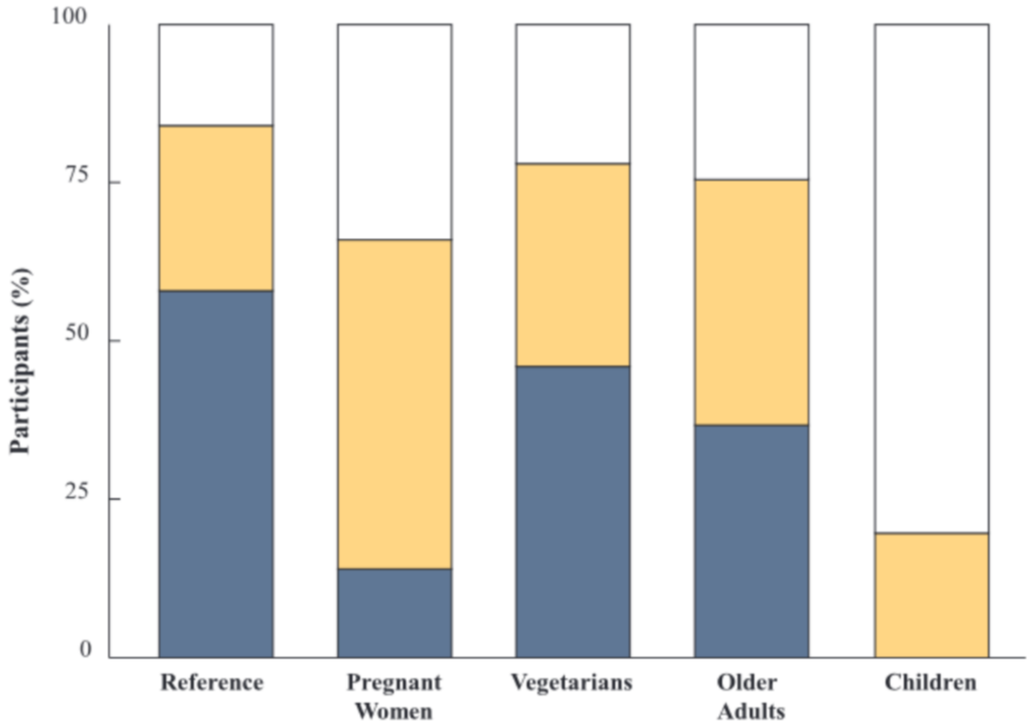

Fig. 1. Distribution (%) of carbamazepine concentrations (above LOQ, blue; between LOD and LOQ, yellow; and below LOD, white) within each study group. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Figure 4: Study on carbamazepine in human urine (Schapira u. a. 2020)

Carbamazepine is just one medicine that is a known compound found in TW irrigated produce. Stricter regulations and further research are needed for pharmaceuticals to consider their stability in the environment and to exclude possible health impacts due to unwanted consummation when irrigated with TW. Antibiotic resistance is a rising problem in societies and needs to be researched when considering TW irrigation and health risks (Christou u. a. 2017).

5. Discussion

To answer the three proposed questions, namely first *Why are studies on irrigation with treated wastewater (TW) and their possible impacts on health relevant?* The paper depicts that an uncontrolled wastewater use brings many possible risks for human health and the environment. Due to scarcity of water and rise in demand, studies increase on TW and are relevant for good health risk assessments. Carbamazepine and boron are the case studies examined in this paper in order to answer the question *What are examples of contaminating substances that are passed on via TW irrigation?* Rising one example on a possible human health risk and one having an environmental impact.

And to lastly answer the question *What can be done in order to prevent health risks of TW irrigation?* It is health risk assessment at an early stage and precise and long-during studies that can make irrigation with TW sustainable, healthy and lucrative and several measures can be implemented. Besides a stringent water treatment, monitoring, adherence to (inter)national guidelines and standards, for the use of treated wastewater in agriculture, can allow a safer irrigation. These guidelines provide recommendations on water quality, irrigation practices, crop selection, and post-harvest handling to minimize health risks.

To consider the best and proper irrigation practices, a good crop selection and management, by choosing the ones that are less prone to accumulating contaminants from irrigation water, can further reduce potential health risks. Finally, public awareness and education on handling the treated wastewater and its produce as a farmer, researcher, worker and consumer (washing and cooking of produce) to minimize potential exposure to contaminants is important, as well as regulatory control and enforcement to ensure adherence to safety standards. By implementing these measures, it is possible to minimize health risks associated with treated wastewater irrigation and ensure the protection of public health and the environment.

6. Conclusion

The paper has explored the challenges and potential health risks associated with the irrigation of agricultural land using treated wastewater (TW). With increasing water scarcity and the growing demand for food, TW irrigation has emerged as a promising solution. However, it is essential to address the potential impacts on human health to ensure sustainable and safe practices.

The study has focused on Israel as an exemplary case due to its extensive experience with TW irrigation and the abundance of scientific research on the subject. The findings highlight the importance of careful regulations and comprehensive assessments to mitigate health risks and protect both human health and the environment. TW irrigation can pose potential risks if the wastewater is not adequately treated or if it contains contaminants. Wastewater can contain chemical compounds and biological pathogens that, if consumed through food or contact with the human body, may lead to acute illnesses or long-term health effects.

To minimize health risks associated with TW irrigation, a thorough health risk assessment is crucial. This includes analyzing the quality of treated wastewater, identifying potential contaminants, assessing exposure pathways, estimating toxicological effects, and implementing appropriate mitigation measures. Israel serves as a model for other countries facing water scarcity, with its advanced technologies and comprehensive approach to water reuse. Through extensive field studies and the implementation of standards, Israel has managed to address specific contaminants such as boron and pharmaceuticals like carbamazepine. The removal of boron from wastewater and the reduction of carbamazepine residues have shown positive results, emphasizing the significance of long-term studies and sustainable product use.

While Austria, with abundant freshwater resources, currently uses little to no TW for irrigation, increasing pressures on water resources due to climate change necessitate long-term adaptation. Austria's strict control and adherence to environmental and health standards, along with upcoming EU regulations on water reuse, ensure the protection of human health and the environment.

To prevent health risks associated with TW irrigation, several measures can be implemented. These include stringent water treatment processes, adherence to guidelines and standards, monitoring practices, and selection of crops that are less prone to accumulating contaminants. Public awareness and education on handling TW and its produce, as well as regulatory control and enforcement, are vital to minimize potential exposure to contaminants.

In conclusion, the paper highlights the relevance of studies on TW irrigation and its potential impacts on health. By conducting comprehensive health risk assessments and implementing appropriate measures, TW irrigation can be made safe, sustainable, and beneficial for agricultural practices. Ensuring the protection of public health and the environment requires collaboration between policymakers, researchers, farmers, and consumers to promote responsible practices and minimize health risks associated with TW irrigation.

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8. List of figures