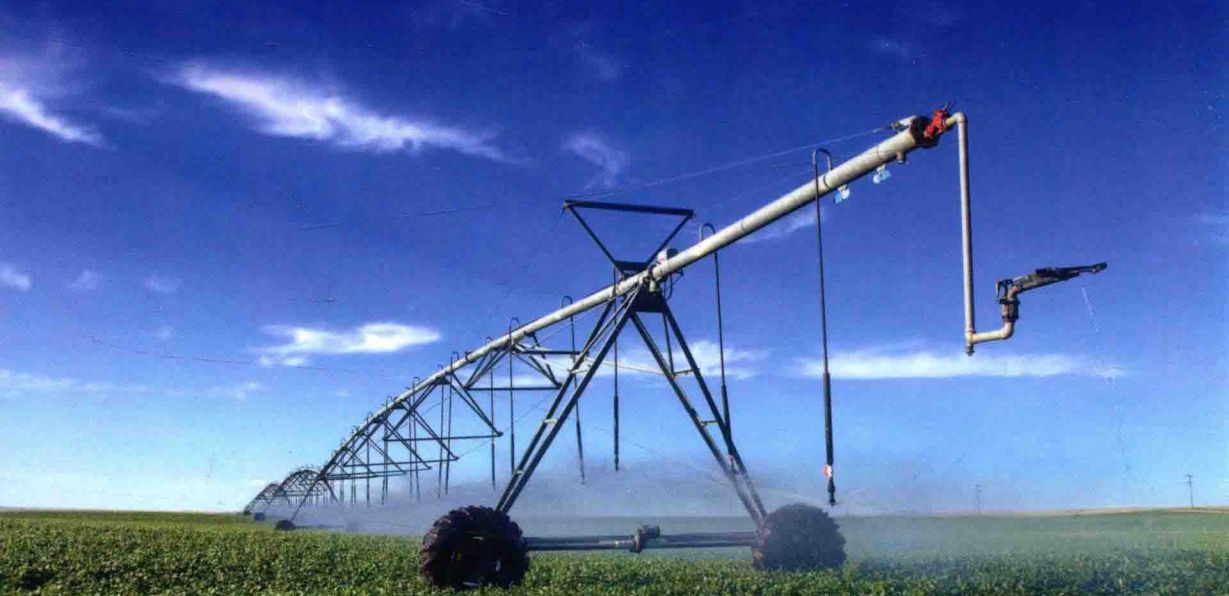
Treated Wastewater in Agriculture

USE AND IMPACTS ON THE SOIL ENVIRONMENT AND CROPS



EDITED BY

GUY J. LEVY | PINCHAS FINE | ASHER BAR-TAL



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Use and Impacts on the Soil Environment and Crops

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Preface

Irrigated agriculture produces one-third of the world's crop yield and half the return from global crop production. Yet, in many parts of the world, especially in semiarid and arid regions the future of irrigated agriculture is threatened by existing or expected shortages of freshwater. These shortages result mainly from the ever-increasing demand put upon water resources by the world's rapidly growing population and their improving standard of living. The constant rise in population and in water use per capita leads also to an ever-growing volume of municipal sewage water which requires to be disposed. Water recycling and the use of treated municipal sewage effluents, (herein referred to as treated wastewater (TWW)) for agriculture, industry and non-potable urban and environmental applications can afford a highly effective and sustainable strategy to exploit a water resource in areas afflicted by water scarcity. Irrigation with TWW can contribute a significant quantity of nutrients, and hence can contribute to the conservation of diminishing resources.

However, irrigation with TWW is not free of risk both to crop production and the soil environment. Potential risks include reduction in yield due to elevated salinity and specific ion toxicity, migration of pollutants towards surface- and groundwater, and deterioration of soil structure. It is important, therefore to understand the way in which parameters such as quality of TWW, irrigation management practices, and soil and crop characteristics affect processes occurring in the irrigated field.

The central role that irrigated agriculture plays in food production, coupled with the increasing need to utilize TWW for irrigation, motivated this attempt to assemble relevant core knowledge and recent advances in research on irrigation with TWW in the form of a comprehensive book. Our goal was to prepare a volume that consolidates the state-of-the-art knowledge on the various aspects of irrigation with TWW and analyzes the possible impacts (either positive or negative) of such irrigation water, both from the agricultural and the environmental perspectives.

The book is divided into 14 chapters arranged in two parts. The first part includes four chapters that cover technical, regulatory, and economic aspects of TWW reuse. The first chapter takes the reader step by step through the multitude of processes available for the treatment of municipal sewage effluents, from extensive, low-tech processes such as lagooning and constructed wetlands to enhanced tertiary and quaternary processes, all aimed at providing TWW that comply with quality criteria set by local and international regulators.

Treatment of sewage effluents should lead to the effective control of health hazards associated with the use of TWW and safeguard the farming community, the consumers of crops, and the population at large from exposure to pathogenic microorganisms that are originally present in the treatment stream. The second chapter deals with the question of what constitutes sufficient protection of the public welfare and introduces the idea that it might be socially and morally justified to allow exposure of the population to a

predetermined and well-regulated level of risk to be associated with the reuse of TWW. The author endorses an approach to treating sewage effluents for agricultural use based on the assessment and characterization of the associated risk rather than adoption of the best available technology to treat the sewage effluents to an excessive, unnecessarily high level.

Chapter 3 presents the most updated regulations and guidelines for TWW use in agriculture embraced by various countries. The different basic philosophies adopted to protect public health and the environment are discussed in this chapter.

The last chapter in the first part (Chapter 4) highlights economic considerations involved in the use of TWW for irrigation. It presents a basic approach to pricing and cost allocation associated with the use of TWW by both large and small farming communities. This chapter also lends support to the role of government as a regulator and an arbitrator regarding the strong external interests and complex economic issues involved in the use of TWW.

The second part of the volume covers the impact of irrigation with TWW on the agricultural ecosystem. The agricultural and environmental aspects of the presence of organic and mineral forms of major nutrients (nitrogen and phosphorus) in TWW are discussed in Chapter 5 (5.1 and 5.2). The fate of organic N and ammonium in soil, including chemical transformations, mobility, uptake by plants, and the risk of groundwater contamination by excessive leaching, as well as emission of greenhouse gases and other losses to the atmosphere, are described and discussed in Chapter 5 (5.1). Examples of experiments and observations in which TWW was used are presented and compared with freshwater. In Chapter 5 (5.2) the fate of inorganic and organic P in soil, including its chemical transformations, mobility, uptake by plants, and the risk of excess P accumulation in agricultural soils and potential contamination of surface water bodies by runoff loaded with P are reviewed and discussed. Results of laboratory studies, field experiments and surveys of plots in which TWW was used are presented and compared with the results of control runs with freshwater. An additional section of this Chapter 5 (5.3) focuses on a subject that thus far has received little attention, namely the chemistry of calcium and of carbonates in TWW-irrigated soils. This topic is important from the environmental point of view because TWW contains relatively high concentrations of carbonates (and in particular bicarbonates), and their accumulation in soils and groundwater may be an important pathway of carbon sequestration.

The inorganic constituents, the concentrations of which in TWW are frequently higher than in freshwater, are discussed in Chapters 6, 7, and 8. Chapter 6 focuses on two elements (boron and chloride) that may reach toxic levels in TWW-irrigated soil. Boron reactions and interactions in soils and its uptake, transport, and distribution in plants are reviewed in Chapter 6 (6.1), as is the issue of boron toxicity resulting from the relatively high boron concentration often encountered in TWW. The specific toxicity of the chloride ion to plants is discussed in Chapter 6 (6.2), where a summary of the role of the chloride ion in plant physiology, as well as some examples of the effect on plants of chloride added through irrigation with TWW, are also given. Chapter 7 discusses the fate of heavy metals in TWW-irrigated soils. It highlights the role of two main factors, pH and Eh, that affect the behavior and fate of metals due to these parameters' strong influences on the solubility of metals and organic matter and on the properties and stability of the surfaces of the soil's solid components. It is argued that, in many cases, especially when less advanced methods for TWW production and higher irrigation rates are employed, it is the effect of the TWW

on metals already present in the soil rather than on the metals contained in the irrigation water themselves that will govern the mobility and availability of metals in the TWW–soil–plant system.

The fact that TWWs are appreciably more saline than the freshwater from which they originated deserves attention. The salinity of the water increases throughout the long path of TWW formation. In Chapter 8, general aspects of the effect of salinity on crop production are presented, as well as some specific examples of the effect on irrigated trees. Innovative management methods to counteract the damage that may be caused by salinity are highlighted.

The potentially adverse effects on the stability of soil-structure and on the soil's hydraulic properties, which are associated with the elevated levels of certain organic and inorganic constituents in TWW as compared with freshwater are evaluated in Chapter 9. The reviewed literature reveals that reports on the effects of TWW on soil's physical characteristics are inconsistent and that existing knowledge is insufficient to support reliable modeling efforts for predicting the soil's response to irrigation with TWW.

The fate of organic matter and organic contaminants present in TWW and their effect on irrigation systems and the soil environment are discussed in Chapters 10, 11, 12, and 13. Biofilm buildup and its role in clogging irrigation systems, an issue that was often overlooked in the past, is discussed in Chapter 10. Special emphasis is put on the presentation of up-to-date knowledge of the mechanisms of biofilm formation and of state-of-the-art practical information on the effects of biofilm buildup on irrigation systems. Some useful schemes to minimize problems associated with biofilm formation are presented. Chapter 11 reviews the impact of various components of TWW, including microorganisms, on the soil's microbial population and activity. High levels of mineral solutes, as well as of dissolved organic carbon, detergents, pharmaceuticals, pollutants such as pesticides and other organic chemicals and trace metals, may affect the diversity, structure, and functioning of microbial communities, and hence also affect soil fertility and structure. The authors conclude that current knowledge on the effects of TWW on the soil microflora is insufficient. Especially lacking are data on the effect of the various components of TWW, separately or in combination, on the composition of the microbial community in soils.

Chapter 12 reviews the long-term risks posed by the potential interactions between the dissolved organic matter in TWW and anthropogenic chemicals present both in the soil and in the TWW. Special emphasis is put on the binding of anthropogenic chemicals to TWW-originated dissolved organic matter and the resultant possibility of enhanced transport of pollutants to groundwater. The characteristics of the organic matter in TWW and its influence on the soil organic matter are discussed in Chapter 13. Based on available knowledge, it is concluded that addition of dissolved or particulate organic matter through irrigation with TWW can ultimately result in either an increase or a decrease in the soil's organic matter content, depending on site-specific soil properties and conditions and microbial activity.

Transport of water and solutes in the soil profile as affected by irrigation with high sodium adsorption ratio (SAR) water is described in Chapter 14. High SAR values are common in TWW. The results of the flow and transport simulations discussed in Chapter 14, suggest that on the field-scale, under realistic flow conditions and over an extended period of time, the adverse effects of low solute concentration and a relatively

high SAR on the flow and the transport are smaller as compared with the effects measured in laboratory systems in which the transport obeys the classical Darcy equation. These systems (unlike the conditions in the field) consist of a one-dimensional vertical, spatially homogeneous flow domain. This finding has practical implications regarding the use of TWW for irrigation. The data presented may be used for water quality classification as related to soils of different textures and as a tool for water and soil management.

In as much as this book covers a wide range of topics related to the use of TWW, it may serve as a reference book for scientists, agronomists, engineers, ecologists, and students. Hopefully, this volume will contribute to the continuation of capacity building in the many areas related to the use of TWW for irrigation and to optimizing the impact of irrigation with TWW on the agricultural ecosystem and the environment at large.

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