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Agrochemicals in Soil and Environment

Impacts and Remediation

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ISBN 978-981-16-9309-0 ISBN 978-981-16-9310-6 (eBook)
https://doi.org/10.1007/978-981-16-9310-6

This Springer imprint is published by the registered company Springer Nature Singapore Pte Ltd.
The registered company address is: 152 Beach Road, #21-01/04 Gateway East, Singapore 189721, Singapore

Foreword

'Man is the only animal that fouls its own nest'. This quote sits true when we think about the rising use or rather abuse of agrochemicals in modern-day agriculture. In the quest for better profitability, agrochemicals came into existence but eventually they have become a major source of environmental pollution. Harmful impacts of agrochemicals are embedded in soil, water, air and even in human health. The rising trend of abuse of agrochemicals, which were introduced in the market in order to improve crop quality, is alarming. Thus, it requires mass spread of awareness as well as implementation of proper guidelines with sustainable and strategic planning for lowering their impact on the environment and ultimately humans.

M. Naeem and team did a commanding job to compile a comprehensive volume on the very important and challenging area '**Agrochemicals in Soil and Environment: Impacts and Remediation**'. The editors have nicely teamed up with the global subject experts to cover up a variety of chapters on agrochemicals and their impact on crop productivity. This book comprises five parts: Part I constitutes of an overview of agrochemicals in soil and environment with an in-depth discussion on what imbibes agrochemical pollution and highlighting studies where they are found in the soil and environment. Following the introduction, this part discusses detection, treatment and remediation measures detailing occurrence, source and type of agrochemicals with their environmental impacts and describes their strategic abatement. It also details the effect of agrochemicals on the texture, productivity, native microflora and nutritional balance of the soil microbiome. Various management strategies including the 4-point plan have been described in this part with a step-by-step approach to the management of agriculture pollution. Further advantages and challenges for developing an intergenerational community-based approach against agrochemical pollution have been highlighted. Part II discusses integrated pest management strategies on providing proper guidance to farmers for handling of pesticides and a detailed demonstration of how pesticides end up in every part of our ecosystem especially air, water, food wildlife, etc. Further, this part explains the magnitude of this problem with examples of deltamethrin (insecticide) and glyphosate (herbicide) by discussing their harmful effects on environment, wildlife and humans. Later in this part, abuse and impact of insecticides on the environment with proper management strategies have been suggested.

In Part III, the chapters include an in-depth mobility assessment of trace elements in the soil and ecosystem. This is followed by a detailed discussion on the serpentine soil–plant relations in order to analyse the effects of nutrient enrichment on low nutritional ecosystems. In addition, how soil erosion and sedimentation can deeply impact agriculture as contaminants have been elaborated in one of the chapters in this part. Lastly, plastics and their detrimental environmental impacts have been reviewed. Further, Part IV goes on to discuss heavy metals such as lead and cadmium and their impacts on plants and human health in addition to exploring the link between crude oil and heavy metal contamination in the farmlands. Lastly, this part strategizes to alleviate arsenic stress from cultivated plants along with guide lining implementable management tips to ward off trace elemental effects from the soil.

Lastly, Part V consists of various remediation strategies for agrochemicals present in the soil and environment along with toxicity alleviation of heavy metals from agricultural crops through the use of metal-resistant bacteria. In addition, bioremediation strategies are employed to mitigate the impact of atrazine from the environment as well as aspergillus-mediated bioremediation of agrochemicals have been expanded in detail in its chapters. The implications of using phytohormones as agrochemicals under dynamic environmental conditions have also been explored in this part. Finally, the role of genetically modified bacteria for alleviating of agrochemical impact on the environment as well as use of omics as molecular blueprint for agrochemical remediation has been discussed in detail. In conclusion, although marketing agrochemicals as fancy pesticides, insecticides, fungicides, rodenticides, etc. is no doubt profitable and intriguing, it is also undeniable that it is also leading us towards a future with polluted soil and environment. Thus, this book was written in order to instil awareness and explore proper management strategies so as to promote a judicious and conscious approach towards the production, marketing and abuse of agrochemicals.

The challenges of agrochemicals in soil and environment are visible and I heartily appreciate the editors and contributing author's dedication to discuss the impact of agrochemicals and remediation strategies that can address the problem significantly.

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Preface

Various anthropogenic activities pose a serious threat to the agriculturally suitable land due to the release of hazardous waste substances therein. The extensive use of agrochemicals (pesticides, fungicides and insecticides), mining, unplanned disposal of municipal waste and other agrochemicals are the major causes of agricultural land contamination, thus degradation. Due to the rapid increase in urban global population, urbanization, industrialization and uncontrolled anthropogenic activities are resulting in the accumulation of large amounts of toxic substances into the environment. These effluents enter into the food chain through the soil and ultimately affect plant and human health. Various metals, metalloids, radioactive substances and other hazardous, toxic organic and inorganic substances are the most prevalent forms of environmental contaminants; their complete remediation in soils and sediments is rather a difficult task. Concerns of their toxicities led to the emphasis on the development of effective techniques to assess the presence and mobility of contaminants in soil, drinking water, irrigation water, and wastewaters. These toxic substances seriously hamper the developmental processes of agriculturally important crops. Furthermore, an increase in global population and advancement in modern agriculture technology has amplified the demand for agricultural/exotic crops and livestock.

Effective management strategies and skills for the agricultural contaminants pave the way to combat the challenges to improve the production of agricultural crops. Judicious application of targeted, and balanced quantities of agrochemicals are necessary for optimal crop production without much environment and yield penalty. At the same time, every effort should be made to improve the availability and use of secondary- and micro-nutrients, organic fertilizers and soil-conservation practices to develop overall crop production in an efficient and environmentally sustainable manner, without sacrificing soil health and/or crop yield. We hope that this book can help in the development of significant applications that feature the integration of modern technologies to remediate contaminated soil environment.

Therefore, it is a need of the hour to undertake these challenging issues rising day by day in the field of agriculture and environmental sciences. We intend to bring forth a comprehensive volume '**Agrochemicals in Soil and Environment: Impacts and Remediation'** highlighting the various prospects that are being involved in the current scenario. This book consists of 25 chapters that are categorized into different

parts, written by global field experts. We are hopeful that this comprehensive volume would furnish the need of all researchers who are working or have great interest in this particular field. We are highly thankful to Springer Nature Singapore Pte Ltd. for compiling this scientific task. Heartfelt thanks are expressed to the team members (Eric Stannard, Akanksha Tyagi, Lenold Esithor and others) for their dedication, sincerity and friendly cooperation in producing out this volume.

With great pleasure, we extend our sincere thanks to all the contributors for their timely response, their outstanding and up-to-date research contribution and their support and consistent patience.

Lastly, thanks are also due to well-wishers, friends and family members for their moral support, blessings and inspiration in the compilation of this book.

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About the Editors

M. Naeem is an Assistant Professor in the Department of Botany at Aligarh Muslim University, India. His research focuses on escalating the production of commercially important medicinal and aromatic plants and their active principles using a novel and safe technique involving depolymerized polysaccharides as well as the application of potent PGRs. His research also focuses on abiotic stress tolerance in medicinal plants. He has published around 100 research papers in reputable international journals. Also, he has authored ten books and co-authored several book chapters published by international publishers. Based on his research contributions, he has received multiple awards and recognitions.

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Abid Ali Ansari is working as Associate Professor at the Department of Biology, Faculty of Science, University of Tabuk, Saudi Arabia since December 2010. His research areas include Plant Ecology and Environment, Eutrophication, Phytoremediation and Plant Biodiversity. He has 16 years of research and teaching experience. He has to his credit 56 research articles, 15 edited books and 26 book chapters with the publishers of national and international repute. He has carried out 8 Research Projects funded by Deanship of Scientific Research, University of Tabuk as Principal and Co-Investigator. He has been awarded Research Excellence 2013 and 2015 and Distinguished Faculty 2020.

Sarvajeet Singh Gill is presently working as Assistant Professor at Centre for Biotechnology, Maharshi Dayanand University. He has approx. 50 book chapters, published over 100 peer-reviewed publications in the journals of international repute and edited 30 books on the subject published by international publishers. He has carried out four R&D projects funded by prominent national funding agencies. He has 17,307 Google Scholar citations, h-index 45 and i10 index 92, whereas, on Scopus, he has 10779 citations, h-index 35. He was awarded NESA Junior Scientist of the Year Award 2008; DST-SERB Fast Track Young Scientist award in 2012; prestigious Web of Science 'India Research Excellence and Citation Award-2017', appeared in 2% global scientists list (2020 and 2021); and Teaching and Committed Research Award 2021.

Part I

Overview of Agrochemicals in Soil & Environment

Agrochemicals in Soil and Environment: An Overview

1

Ritu Gill, M. Naeem, A. A. Ansari, Anil Kumar, Ajit Kumar, Ashmita Chhikara, Juan Francisco Jiménez Bremont, Narendra Tuteja, and Sarvajeet Singh Gill

Abstract

Frequently changing environmental conditions pose serious threat to the global agriculture by putting extra burden in the form of environmental insults (biotic and abiotic factors) and challenge to food security, and thus, the global population. To ensure the food security, optimal production of agriculture is essential. Judicious and safe use of agrochemicals (like chemical fertilizers, pesticides, and plant growth regulators) has enormous potential to boost the agriculture

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M. Naeem et al. (eds.), *Agrochemicals in Soil and Environment*,
https://doi.org/10.1007/978-981-16-9310-6_1

productivity for meeting the food demand of rapidly growing population, but excessive use causes serious damage to the environment and contaminate the soil, water, and whole ecosystem, thus threatening the soil micro biota and soil health sustenance. The continuous use of agrochemicals often results in accumulation of metals/polychlorinated biphenyls, etc. in soil and water, and thus the food chain, and damages the human/animal health. Therefore, research on soil health and adoption of alternative measures in the form of compost and vermicompost, yard and green manures, biopesticide, beneficial fungi, and plant growth-promoting rhizobacteria are essentially required. Remediation or restoration of degraded soil can be achieved through microbe consortium/nano and biochar-assisted breakdown chemicals/pesticides.

Keywords

Agrochemicals · Environmental contamination · Fertilizers · Pesticides · Remediation approaches

1.1 Introduction

In the era of frequently changing environmental conditions/global climate change, feeding the ever-increasing population is a serious challenge, and to ensure the food security, the use of various agrochemicals increased the crop productivity, food yield, fiber content, and also helped in preventing the vector-borne diseases, but extensive research on the impact of agrochemicals revealed that their use has harmed the human and environmental health significantly (Speight 2016). It has also been reported that the presence of various agrochemicals in plant and soil system happens to be the main reason of their presence in the food chain and drinking water contamination (Sarkar et al. 2020).

Large agrochemicals represent a group of chemical substances (pesticides and chemical fertilizers) that ensure high crop productivity and safety against plant pathogens like different pesticide compounds, insecticides, herbicides, fungicides, nematicides, etc., but luxurious use of agrochemicals has contaminated environmental components such as agricultural soil, canals, rivers, etc. and the high presence of nitrate causes toxicity in plants and animals and thus poses serious health hazard (Ravichandra 2018). Among all the continents, Asia has topped the chart with 52.8% of pesticide consumption, followed by America, Europe, Africa, and other countries. In Asia, China is the primary consumer of pesticides, and globally, Saint Lucia has occupied the first position (FAO 2019). Different types of chemical fertilizers like urea, di ammonium phosphate, super phosphate, ammonium sulfate, calcium ammonium nitrate, calcium nitrate, etc. are being extensively applied to increase the produce of the crops, but their leftover presence in the soil and environments causes toxicity in plants, animals, humans, and in friendly microorganisms and earthworms. Comparatively, pesticides show their long presence in the soil may be because of their slow decomposition in the inactive soil system. The physical factors such as rainfall, heat, soil or water pH, moisture, and ultraviolet rays also decide the fate of

pesticides' persistence in the environment. It has also been observed that the chemical composition of the pesticide and its water solubility/volatility and method of pesticide application also define their persistence in soil. Researchers have also demonstrated that certain bioaccumulative pesticides such as aldrin, chlordane, dichlorodiphenyltrichloroethane, dieldrin, and toxaphene showed toxicity and long stay in the biological system. The application of higher doses of pesticides and regular application induce severe toxicity in the environments (Wang et al. 2008; Sumalan et al. 2010).

Therefore, it is imperative to remediate the contaminated agricultural soil and water by adopting sustainable measures like plant-microbe partnership for bioremediation of ACs, earthworm-assisted bioremediation of ACs, and soil-biochar formulations for improved absorption and reabsorption of ACs, nanoparticles, and nanoformulations.

1.2 Agrochemicals

An agrochemical is a contraction of agricultural chemical used in agricultural practices. Agrochemicals are basically used to kill or prevent the wild grasses/weeds or the microorganisms (bacteria, fungi, virus, etc.), pests which can pose yield penalty (Pandya 2018). Agrochemicals refer to pesticides such as insecticides, herbicides, fungicides, nematicides, synthetic fertilizers, hormones, and other chemical growth agents (Fig. 1.1).

The Food and Agriculture Organization of United Nations (FAO 2021a) describes that pesticides are any substance or mixture of substances of chemical or biological ingredients intended for repelling, destroying or controlling any pest, or for regulating plant growth. The term pesticide applies to insecticides, herbicides, fungicides, rodenticides, molluscicides, wood preservatives, and various other substances used to control pests. Pesticides also include plant growth regulators, defoliants, and desiccants (https://www.fao.org/news/story/en/item/1398779/icode/).

Pesticides' use increased in the 2010s by more than 50% compared to the 1990s, with pesticides' use per area of cropland increasing from 1.8 to 2.7 kg/ha. Global pesticides' use in agriculture remained stable in 2019 at 4.2 million tons, equivalent to 0.6 kg/person. Pesticides' use in agriculture in Europe increased by just 3% between the 1990s and the 2010s. Total pesticides' trade reached approximately 5.6 million tons of formulated products in 2019, with a value of USD 35.5 billion.

FAO (2021a) reported the regional total pesticide uses for the same period, in particular the recent stabilization in Asia. Pesticides' exports from Asia decreased in the most recent years from 2.6 Mt in 2017 to 2.5 Mt in 2019. The region is responsible for about 60% of global insecticides use in the 2010s. Pesticides' use in agriculture in Europe increased by just 3% between the 1990s and the 2010s, most likely due to the stringent European Common Agricultural Policy put in place, which monitors and controls the use of pesticides (Fig. 1.2).

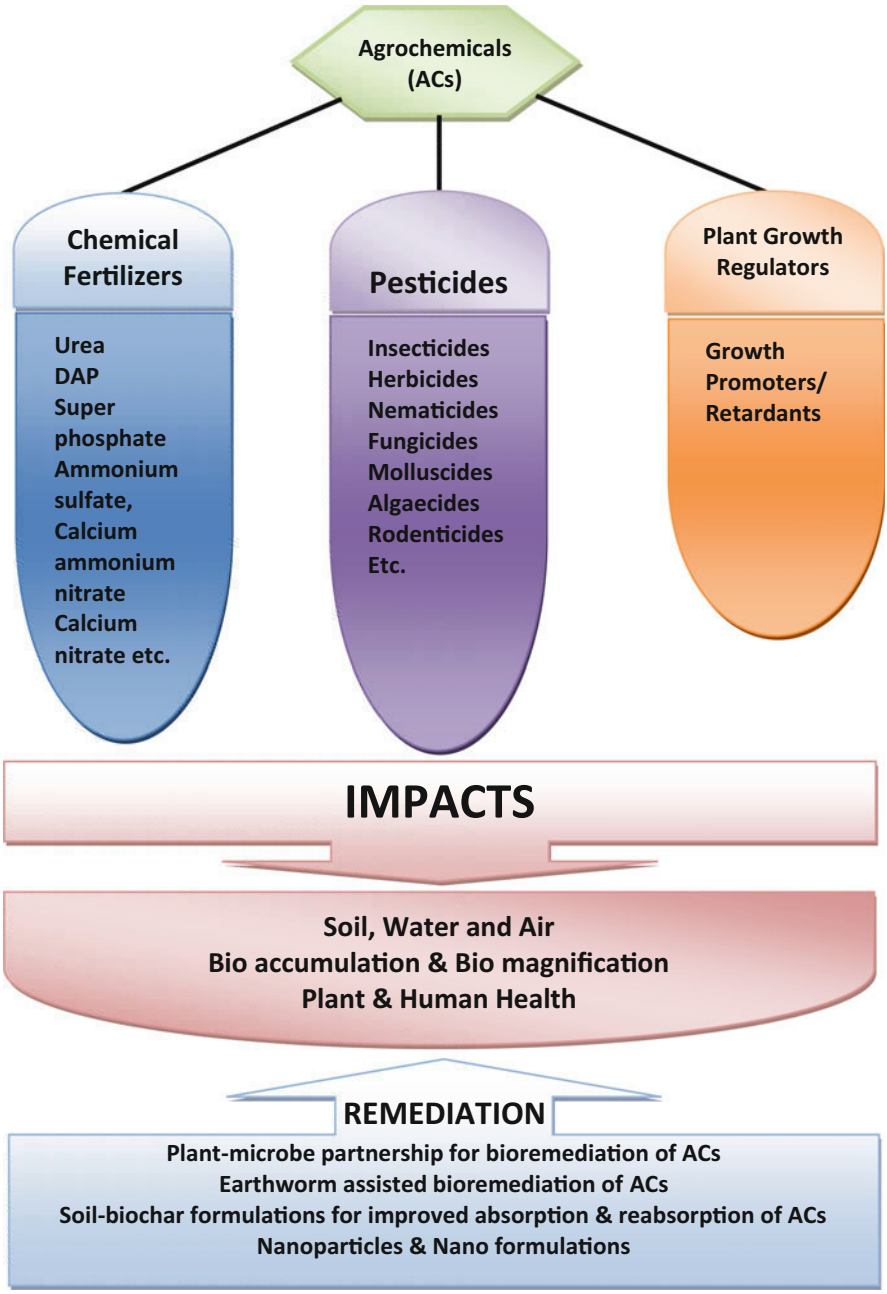

Fig. 1.1 Agrochemicals' impact and remediation