1

Introduction

Shima Shayanfar and Suresh D. Pillai

Managing industrial, agricultural, and municipal wastes is a challenge that countries around the world must grapple with. Rapid urbanization coupled with the increasing demands that the growing population creates requires that technologies need to be harnessed to provide a sustainable approach toward managing wastes. According to 2018 US EPA data, an average American generates approximately 5 pounds of municipal solid waste each day, which ultimately results in a total of approximately 292.4 million tons of municipal solid waste (MSW) generated each year (EPA, 2018). Municipal waste refers to waste that consumers discard, which includes bottles, corrugated boxes, food, grass clippings, sofas, computers, tires, and refrigerators. This MSW does not include construction and demolition debris, municipal wastewater sludge, and non-hazardous industrial wastes. Local and state governments must deal with growing urbanization and shrinking land-filling or other disposal options, and therefore reduction of MSW wastes and recycling of wastes are of high priority. Only 69 million tons of MSW (23.6%) of the total MSW were recycled, of which corrugated boxes were the primary waste. In 2018, 34.6 million tons of MSW (12%) were combusted with energy recovery. Food made up the largest component of MSW that was combusted. Approximately 50% of MSW was landfilled, out of which food was the largest component. Historically, the per capita generation of MSW increased from 2.7 pounds per person to approximately 5 pounds in 2018. There are, however, positive trends in terms of volume of MSW that is landfilled, which has decreased from 94% in 1960 to 50% in 2018, and the volume of MSW that is converted into energy, which has increased from 0% in 1960 to 12% in 2018. In the US, more than 16,000 wastewater treatment plants are in operation today, treating around 150 billion liters of wastewater per day. In total, these treatment plants generate approximately 13.8 million tons of treated sludge annually (Seiple et al., 2017). Approximately 54% of these treated sludges (biosolids) are beneficially reused, mostly on agricultural soils and smaller amounts for re-forestry programs and urban areas (US EPA, 2003). Wastewater reuse using either direct or indirect potable reuse is in operation in many parts of the arid Southwest and in California. The European Union and its member states have also adopted proposals to create an economic incentive for the upcycling of

Ionizing Radiation Technologies: Managing and Extracting Value from Wastes, First Edition. Edited by Shima Shayanfar and Suresh D. Pillai.

wastes. It is projected that by 2025 there will be a complete ban on the landfilling of recyclable wastes in the EU and by 2030 almost 70% of waste packaging will be recycled.

The recycling of wastes opens the door to extract "value" from wastes. Waste valorization refers to any process that converts waste materials into higher value products by either recycling them or converting them into energy feed stocks. The end-products of waste valorization could include quality chemicals, fertilizers, fuel, and energy as well as products that benefit the local economy. The concept of waste valorization is not new. The goal of waste valorization is to derive value from waste rather than just considering it as waste. The term "waste valorization" is now part of the lexicon of those involved in managing and waste recycling and very much part of the discussion of sustainable urban development. Even though the concept of waste valorization is not new, the growing need for cost effective and sustainable management of wastes, the rapid depletion of natural resources, the challenges facing the fossil fuel industry, as well as the rapid advancement of technologies for extracting value from wastes have spurred a wider interest in waste valorization. The concept of wastes as a "resource" can also create a positive public image that is critically necessary for societal buy-in for investing of resources into waste valorization programs. For example, the wastewater industry refers to municipal wastewater treatment plants as resource recovery facilities (rather than the traditional wastewater treatment plants) highlighting the significant value of municipal wastewater as pools of carbon, nitrogen, and phosphorus. Agricultural wastes from farm operations and animal husbandry also generate significant volumes of wastes that are also rich sources of essential nutrients as well as high-value pharmaceuticals. Even though many if not most of the current valorization technologies in use today involve a significant input of energy and chemicals, these technologies have resulted in a spectacular diversity of options for extracting value from waste.

Ionizing technologies, which include gamma irradiation, X-ray irradiation, and electron beam (eBeam) irradiation, are a suite of technologies that can have a major impact on making current waste valorization economically and environmentally more sustainable. Ionizing radiation is a non-thermal technology that has found a variety of applications in modern society including sterile insect technology, phytosanitary treatments, food pasteurization, medical device sterilization, and wastewater treatment and recycling of municipal sewage sludges. A major value proposition of this suite of technologies is that these are non-thermal technologies and there is no requirement for the input of chemicals into the process. These features make these technologies ideally applicable to the discussion of green, environmentally, and economically sustainable technologies. There are significant research advances to the use of ionizing technologies in the recycling and reuse of industrial, agricultural, and municipal wastes. The Vienna-based International Atomic Energy Agency (IAEA) as part of its "Atoms for Peace and Development" has convened several collaborative research groups to advance research and development in this area. The advances from these projects have been compiled into a TECDOC (technical document) that the IAEA has published (IAEA, 2014).

To the best of our knowledge, there is no reference book on the market that attempts to compile all the different applications of this technology for the different waste streams and possible applications. This book, *Ionizing Radiation Technologies*, was motivated by the interest in spurring research, development, and commercialization of these technologies in the waste valorization industry. It is meant to highlight the major advances taking place in how ionizing technology is being harnessed and could be further harnessed to derive high-value end-products from agricultural, municipal, and industrial wastes. The book provides the reader with a broad overview of the value trapped in waste streams and how a strategic application of ionizing technologies can be valuable from both the environmental perspective as well as the economic perspective. This book will be a valuable addition to the other books in the market that deal with sustainability and green technologies.

The book initially discusses the ionizing radiation technologies such as gamma (Cobalt-60) irradiation and high- and low-energy electron beam (eBeam) technologies. The subsequent chapters focus on specific applications of these technologies to derive value (energy/nutrients/high-value chemicals) out of agricultural wastes (such as bagasse, lignin, animal wastes, animal feedlot wastes), municipal (domestic sewage sludge and effluent) and industrial waste streams. Each of the chapters under these main subject heading discuss the original research that has been published in the respective areas, including discussion of research data and possible future research directions. There is also a section on the economics of waste valorization with chapters on how to calculate the economics of deriving value from different waste streams and discussion of possible business models.

This book is targeted as a reference book aimed at both students, researchers, and practitioners. The primary audience is environmental consulting engineers and waste industry professionals tasked with waste management and valorization. The other intended audience includes researchers, graduate and undergraduate students, as well as the investment community and the technology developers. This book can serve as a resource for students majoring in food science and technology, animal industries, biological and agricultural engineering, ecosystem science and management, and environmental and sustainability engineering. A secondary audience is government agencies, international organizations such as the IAEA, UNDP, and the FAO, and non-governmental organizations that are focused on waste management, environmental sustainability, and urban planning.

References

EPA. (2018). https://www.epa.gov/facts-and-figures-about-materials-waste-and-recycling/national-overview-facts-and-figures-materials (accessed 18 April 2021).

IAEA. (2014). Radiation Processed Materials in Products from Polymers for Agricultural Applications. IAEA-TECDOC-1745.

Seiple, T., et al. (2017). Municipal wastewater sludge as a sustainable bioresource in the United States. *Journal of Environmental Management*, 197, 673–680.

US EPA. (2003). Environmental Regulations and Technology: Control of Pathogens and Vector Attraction in Sewage Sludge.