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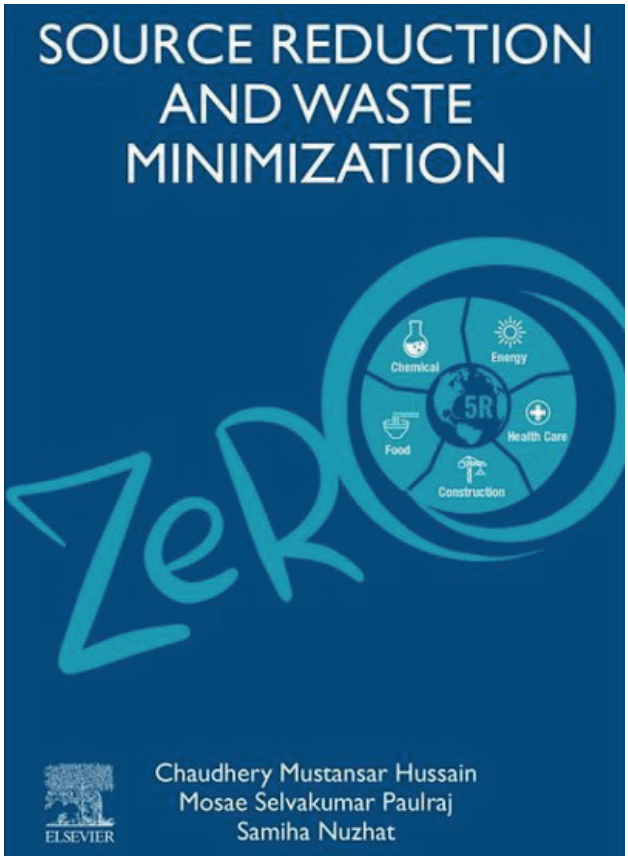

SOURCE REDUCTION AND WASTE MINIMIZATION

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The book "Source Reduction and Waste Minimization" bases its core principles on the concept of industrial waste prevention, considered by the authors as the best strategy to waste issues, according to the motto "Prevention is better than cure". The authors investigate this topic from the point of view of several industrial sectors, adopting a schematic approach to highlight the types of waste generated in each sector and the related available strategies to minimize waste at the source. For each sector, source-level waste minimization strategies are discussed in terms of the available alternatives for product substitution, process modification, recycling and reusing options, and the regulations and policies in force worldwide. Case studies are also described as examples of best practice.

The book is divided into 11 chapters. After an initial overview (Chapter 1) on commonly produced hazardous waste, on the principles of sustainable waste management and its advantages given by both waste prevention and treatment processes, in Chapter 2 the book starts dealing with the latest technologies and processes for solid and liquid waste treatment and for energy production from waste. Chapter 3 is specifically dedicated to waste production and minimization in the electrical and electronics industries. In Chapter 4, the authors analyze the strategies available in healthcare industries and the related policies. The construction industry is the subject of Chapter 5, while Chapter 6 is dedicated to review the latest issues, strategies and policies in the chemical industry. In Chapter 7 and Chapter 8, the focus moves respectively to the food industry and to the energy production sector. Chapter 9 deals with source reduction and waste minimization in the textile industry, while the mining industry is the topic of Chapter 10. In the last chapter (Chapter 11), final remarks, challenges and recommendations are presented.

The initial overview presented in Chapter 1 starts with describing the challenges towards waste reduction at the source level, which demands continuous monitoring, evaluation and re-thinking of waste reduction strategies. Minimizing waste at the source is expected to reduce the impacts of waste on health and the environment caused by waste management strategies, while reducing the costs for their implementation. The industrial sector is considered as the main responsible for hazardous waste production. Despite the risks induced, many industries still do not treat their own waste properly nor re-think their production processes, especially in low-income countries. The authors define the concepts of "waste minimization" (waste prevention by modification of industrial processes and product substitution) and "source reduction" of waste (waste treatment carried out inside industries). Besides reducing environmental hazards like source reduction strategies, process modification allows reducing costs and recovering materials. The authors describe the main characteristics of hazardous waste according to the U.S. Environmental Protection Agency's classification and the risks involved during waste production, transport, treatment and disposal. Key principles of sustainable waste management are discussed, including the "3Rs" concept (reduce, reuse, recycle), issues related to the management of solid and liquid waste worldwide and related examples, the importance of integrated waste management schemes rather than single waste treatments/policies to increase the level of environmental sustainability, and the "zero waste" concept as the ultimate desideratum. Finally, the benefits of the co-imple-

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mentation of waste minimization and source reduction strategies are reviewed: besides expected environmental benefits like biodiversity protection and the prevention of greenhouse gas (GHG) emissions, the implementation of both concepts brings advantages in terms of health protection and economic development. Lower emissions of water and local air pollutants from waste management and disposal, and reduced exposure to clinical waste decrease the risk of developing acute or chronic diseases. Lower impacts on healthcare systems and the environment translate to lower societal costs. In addition, the application of the 3Rs principle allows industries saving money or repaying the investments made to improve process sustainability. Finally, the authors list the United Nations' Sustainable Development Goals (SDGs) that waste minimization and source reduction contribute to achieve, specifically SDGs n. 3, 6, 7, 8, 11 and 13.

Chapter 2 describes the most adopted processes and technologies used for waste treatments and resource efficiency. The authors initially dedicate a subsection to illustrate the environmental, health and economic benefits of recycling in both high- and low-income countries. The discussion then moves to mechanical-biological treatments: the authors start from composting (the most consolidated one, but potential source of GHGs) and continue to processes with increasing complexity, like anaerobic digestion, enzyme-mediated conversion of specific substances from both solid and liquid waste streams, membrane ultrafiltration and autoclave for waste sterilization. Electrolysis and pyrolysis are regarded as examples of chemical treatments respectively applied to liquid and solid waste and used for resource recovery and waste minimization. The authors also discuss thermal treatments, whose environmental performance depends on input waste, energy source (if needed) and target output. Incineration is presented as the most common thermal treatment due to its relative simplicity and the possibility to recover energy from waste. However, its drawbacks in terms of the emission of toxic and global air pollutants are also discussed. Alternative thermal processes along with their advantages and limitations are presented: molten-salt oxidation, hydrothermal carbonization, hydrothermal liquefaction and plasma gasification. This chapter continues with the description of available biological and physical-chemical filtration technologies, including biofiltration, activated-carbon filtration, and reverse osmosis. The importance of renewable sources of energy, alternative fuels, communication technologies and advanced waste collection systems is also highlighted. The chapter ends with considerations on the potential benefits given by green chemistry in minimizing the production and use of hazardous substances.

Chapter 3 deals with waste from electric and electronics industries. The high production of waste from electronic and electrical equipment (WEEE) (4,000 t/h, with a constant annual 4% increase) is associated with the toxicity of the materials contained in the devices, including heavy metals (As, Cd, Hg, Mn, Ni, Pb, Sb), persistent organic pollutants and polycyclic aromatic hydrocarbons. As source-level waste minimization initiatives, the authors propose: product substitution (e.g., lithium-ion batteries instead of conventional ones), process modification to improve resource efficiency and liquid/gaseous depollution, metal recycling from WEEE via physical, chemical and biological treatments, recycling of plastics. General principles of worldwide regulations on WEEE are also presented.

Chapter 4 is dedicated to hazardous waste from healthcare industries. Waste minimization and source reduction initiatives are extremely important because of the high risk associated with healthcare waste (HCW) management. Major hazardous HCW components are infectious/pathological, chemical, pharmaceutical, cytotoxic, genotoxic and radioactive waste, and sharp objects. Best practices for source reduction and waste minimization include: source-level HCW separation supported by relevant policies, product substitution (e.g., reusable surgical attires combined with sterilization systems or replacement of hazardous chemicals in pharmaceutical processes), technology substitution, incineration and biochemical treatments (for pharmaceutical industries). Due to the infectious risk of HCW, recycling is more critical than other sectors and applicable mainly for metal waste and machineries. The authors also list proposals for environmental policies to incentivize source-level waste minimization initiatives and regulate product substitution.

Chapter 5 describes the role of the construction industry in waste generation and the opportunities for source-level waste minimization. Being one of the pillars of the economic growth of a country, this sector generates large amounts of waste, which can be broadly classified as solvents, metal, plastic, ceramic, cellulose-based and inert waste. Considered that landfilling is the main destination for construction and demolition waste, source-level waste minimization strategies are crucial for sustainable waste management in this sector. However, treating waste locally on construction sites would be complex and economically unfeasible. Thus, this sector should focus on more viable strategies like product substitution (e.g., by increasing the use of wood), efficient use of materials, reuse (strongly connected to product substitution) and recycling (facilitated by the inert nature of construction materials). A desirable scheme of policies should make site-waste plans as compulsory, set stricter standards for landfilling and reward companies that adopt virtuous approaches.

The chemical industry is the subject of Chapter 6. This sector is responsible for the generation of an extremely large variety of waste, especially in the liquid and gaseous form, whose toxicity levels may vary greatly from one substance to another. The adoption of green chemistry principles straightly leads to chemical substitution and process modification. Recover and reuse of chemicals would ensure cost savings besides lower waste production. In addition, unlike the construction sector, waste can be easily treated locally by biological processes, physical or physical-chemical filtration and sedimentation, chemical and electrochemical processes. Chemical waste standardization is necessary to support improvements in this sector.

Chapter 7 is dedicated to the food industry, which includes a broad range of activities, from food production to food preservation and packaging. Examples of waste from this sector are crop residues, animal waste, packaging and

catering waste. Process modifications would reduce food loss during production and food preparation. Governmental policies should monitor and regulate the use of packaging materials, favoring the transition to more sustainable materials and reuse initiatives.

In Chapter 8, the authors describe the role of the energy production industry in waste generation and its opportunities for waste reduction, with specific reference to non-renewable energy production. Waste byproducts of concern are liquid-form organic pollutants, metals (relevant for hydropower and photovoltaic plants too), radioactive waste (in nuclear power plants) and, in general, organic and inorganic air pollutants. The main source-level waste minimization strategies consist in the replacement of fossil fuels and energy infrastructures with alternative fuels and materials, and the optimization of energy production and use. Despite the known environmental advantages, the photovoltaic (PV) industry suffers from widely applicable solutions to recycle PV panel components. Promotion and incentivization of renewable energy sources are regarded as key policies for this sector.

Chapter 9 deals with the textile industry, which uses a wide variety of fibers, dyes, colors and chemicals in its processes and produces waste that can be mainly divided into spinning, weaving, knitting, dyeing and clothing waste. Product substitution initiatives may involve the use of natural dyes rather than synthetic ones containing heavy metals. Other chemicals may be replaced with enzyme-based solutions, both in the production process and in the biodegradation of dye contaminants. Biotechnologies may also be conveniently applied for wastewater treatment. 3R approaches could also be incorporated: wastewater reuse through membrane-based separation and recycling of fiber-based waste for the furniture industry are typical examples.

In Chapter 10, mining activities like the extraction, management and processing of natural inert materials, fossil fuels, minerals, metallic ores are discussed in terms of waste generation and minimization. This sector produces dust and different types of solid (e.g., byproducts of excavation activities) and liquid (e.g., contaminated process water, oils) waste, some of them being toxic or radioactive. Unfortunately, in this sector there are limited options for product substitution. However, advanced technologies like hydrogel membranes could separate different waste materials and make them available for reuse. In addition, biochemical processes and wetlands could be used to reduce the issue of acid mine drainage.

Chapter 11 discusses the challenges that should be faced to achieve source-level waste minimization targets. According to the authors, an important cause of inaction is the reluctance of the industrial sector in making long-term investments oriented to environmental and economical sustainability. This reluctance is often associated with unaffordable initial investment costs and the lack of supporting policies and incentives by governments. The absence of adequate training programs and facilities for employees is also considered as a possible reason by the authors. The unavailability and complexity of technologies for sustainable production or waste treatment are also limiting factors.

Overall, the book provides the reader with an overview of the available or desirable approaches to reduce waste production from different industrial sectors, along with the current limitations and the improvements needed.

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