Chapter 1
Introduction: Environmental Pollution and Biotechnological Solutions

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Abstract Progress, wealth, comfort, increased productivity and economic growth are some of the repercussions that emerged from the Industrial Revolutions, providing greater benefits and opportunities. But these advances also brought us great challenges, bringing uncertainties for the future. Our social organization, economic models and lifestyles are altering ecosystems and Earth's patterns, causing environmental degradation, and shaping the face of the Earth. But the same revolutions that brought us challenges can provide us with opportunities to restore the environment. And biotechnology can unlock potential solutions for a more sustainable and resilient future.

Keywords Industrial Revolutions · Environmental pollutants · Biotechnology · Bioremediation · Circular economy · Industry 5.0

The Industrial Revolution marked significant and remarkable milestones in human history. They spurred faster progress in several areas that benefit human life and led to economic, political, and societal changes, changing life in unforeseen ways. The First Industrial Revolution began in Great Britain after the 1750s with the introduction of hydraulic power and steam engine, which led to the mechanization of

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T. Encarnação, A. Canelas Pais (eds.), *Marine Organisms: A Solution to Environmental Pollution?*, Environmental Challenges and Solutions,
https://doi.org/10.1007/978-3-031-17226-7_1

agriculture, manufacturing, and transportation. In 1870, the Second Industrial revolution started with the generation of electricity, shortly after its discovery, incorporating electromotive force in the industry, enabling mass production for the first time. A century later, in the 1970s, the Third Industrial Revolution started with the invention of the transistor and the first microchip; the advances in computer technology after the Second World War triggered further development in the automation of the production process. Since then, a digital revolution has been disrupting traditional industries. A technological fusion of physical, chemical, digital, and biological dimensions is transforming industry, economies, jobs, and society itself, leading us to a New Era, the Fourth Industrial Revolution or Industry 4.0. Although no consensually accepted definition exists yet, the Industry 4.0 concept can be described as the advent of cyber-physical systems (CPSs), the Internet of Things (IoT), and services (MinHwa Lee et al. 2018) which have a significant impact on the efficiency of the production processes and in product development. The COVID-19 pandemic forced a rapid transition to digital technologies, even in sectors that were particularly resistant to the digital transition. The development of the Industry 4.0 technologies such as the Internet, Big Data (BD), blockchain, IoT, Additive Manufacturing (AM), virtual and enhanced reality, and Artificial Intelligence (AI) will probably lead us to radical changes, more human-centered, more sustainable, and more resilient: Industry 5.0. Without a doubt, Industry 5.0 (European Commission 2021) will significantly transform the manufacturing processes and services sectors where collaborative interactions between humans, machines, and systems materialize.

Despite the fact that social inequality may be found in all societies, the industrialized world brought us comfort and wealth in our lives. But this comes with a high price to pay: with all the improvements, a rapid urbanization brought significant challenges to the cities that suffered an increased pressure, such as growing population, lack of potable water, and residues management; a high consumption increased the release of pollutants into the environment. Carbon dioxide, dioxins, phthalates, bisphenols, pharmaceuticals metabolites, pesticides, flame retardants, and so many thousands of chemicals are released into the environment every day and have a dramatic impact on human health and wildlife. Although some damages could become irreversible in a very short time, we still have the opportunity to reverse the trend. We must boost science, technology, and innovation to implement biobased solutions to benefit from the progress that industrial revolutions brought us, reducing the environmental footprint. To achieve that, the entire planet needs to be united in a Green Revolution: civil society, governments, companies, and industries, organizations, all segments of society.

We are living a crisis for resources that will push forward the transition to new and renewable raw materials. Allying this with the emergency of the pollutants mitigation, we will be able to create a structure that allows a sustainable evolution of the planet, both in terms of well-being for humans and the environment.

Among all the tasks that should be done in a very short time, bioremediation, which has already started using plants and microorganisms, allow the production of biomass to be used in different feedstock sources for many industries applications:

for instance, bioplastics, fertilizers, new pharmaceuticals compounds, building blocks, energy, and many other exciting solutions, which unlock new sustainable and eco-friendly possibilities. These challenges also create enthusiastic economic opportunities. These economic outputs should be improved by countries with credible, efficient, and concrete policies that enhance the advancement of sustainable technologies. Science should provide the tools and robust evidence to support decisions before these are implemented into legislation for an ecological transition toward sustainable development.

This book aims to contribute to this fascinating process toward the next industrial revolution. The following chapters will comprehensively discuss bioremediation technologies, to reduce environmental pollution while producing value-added biomass that meets the need for new and better sustainable materials. Various marine microorganisms, such as sponges, microalgae, fungi, bacteria, yeasts, and consortiums of different microorganisms, are all able to biodegrade several families of compounds; for instance, carbon dioxide, PAHs, heavy metals, petroleum sludge, naphthalene and pyrene, pharmaceuticals, persistent organic pollutants. Tailored solutions will be discussed with the primary goal of contributing to zero carbon and zero pollution, and groundbreakingly scientific and technological advances will be critically approached. Legislation and regulatory requirements are also an essential topic of discussion and debate since the release into the market of new developed biobased products can be hindered by legal requirements.

Some Industry 4.0 technologies, such as additive manufacturing and Artificial Intelligence, will be debated in the approached context. The massification application of technologies that result from industry digitization plays and will play an increasingly important role in the development of intelligent solutions. Production and treatment systems will be increasingly monitored and controlled in real time based on machine learning. Waste treatment plants, as well as collection systems, present an increasing application of Digital Twins concepts. Digitization is and should be extended to electromechanical systems for the collection and treatment of waste and water to the point that, in real-time, there is such a collection of data that allows the existence of a digital twin, if possible autonomous and controlled by machine learning (Vitorino et al. 2019). The digital definition of systems (more common on electromechanical systems) must also be followed by the digital definition of products and every tangible material. The increasing of understanding on transforming processes and the increasing of optimization, monitoring and control, allow, the spatial and temporal definition of molecular organization, applied (for example) to additive manufacturing. In this way, this depth increasing of digital control is a precursor to a molecular-level definition of meso parts (from molecules to parts). The products of the future will be designed at the molecular level and implemented with digital, spatial, and temporal control (da Silva et al. 2022).

Can we glimpse the future? Can we glimpse the next industrial revolution, Industry 6.0? It is predicted that possible new technologies may include quantum computing and nanotechnologies. But what about changes in our values and our perceptions? Changes in how we socially relate, work, and connect with Nature for many years separated? Perhaps we can come to say: “Industry 6.0 significantly

transformed the world where collaborative interactions between humans, machines, and Nature materialize."

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