Chapter 12
Sustainable Wastewater Management in the Pharmaceutical Industry

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ABSTRACT

Although pharmaceuticals are advantageous to modern civilization in many ways, their use contaminates the environment to which they are exposed. Numerous pathways, such as the release of treated wastewater, sewage from waste dumps, sewer lines, runoff from animal waste, as well as the application of manure fertilizers to land, may allow them to reach the environment. Pharmaceutical wastewater contains organic debris, non-biodegradable chemicals, microbial contaminants, and salt, necessitating advanced treatment techniques due to water scarcity and the persistence of dissolved organic matter. Anaerobic membrane bioreactors are capable of treating intricate pharmaceutical waste, recovering energy, and generating wastewater

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that is rich in nutrients and suitable for irrigation. This chapter discusses the use of anaerobic methods for drug breakdown, highlighting the benefits of wastewater's high organic matter concentration. It also discusses hybrid processes combining physical, chemical, and biological treatments.

INTRODUCTION

As the pharmaceutical industry expands, more attention is now being paid to environmental pollution because of its ecotoxicity and endurance. Owing to the increasing demand for pharmaceuticals, there has been a need to ramp up the production capabilities of pharmaceutical plants. These plants need a steady supply of water whose quality is regulated by the authorities. Following this, the effluents are released into freshwater streams and water bodies or onto the soil and the toxic pollutants eventually find a way to enter the aquatic ecosystem (Minhas et al., 2022). Pharmaceuticals are a broad category of artificial and natural substances that are used to treat, prevent, and cure both acute and chronic illnesses to enhance patient outcomes. Drug science has come a long way in the last few decades toward guaranteeing a safe and healthy life. But these pharmaceutical ingredients are now posing a new environmental risk noted that the cumulative effects of pharmaceutical discharges into the environment affect aquatic ecosystems and result in issues with the health of the public. Precious, low-volume multiproduct plants, mostly batch operations where the effluent is combined and treated, present challenges for the pharmaceutical industry. Bulk drug production is done in a few specialized batches, semi-batch, and continuous process factories. These plants handle a variety of reactants with specialized equipment, including solvents, solids, water, and homogeneous catalysts. In these kinds of units, the kind of impurity, rather than the drug's purity, determines the drug's primary cost. Hence, separation actions are essential to this business (Kadam et al., 2016). Environmental quotient, also known as the “E-factor”, in the pharmaceutical world, ranges from 50 to 100 kg. This is because these methods involve multiple steps, ranging from five to thirty, and multiple non-catalytic routes that require large amounts of volatile organic compound (VOC) solvents (Sheldon, 2023). Numerous organic and inorganic pollutants, including as heavy metals, solvents, active pharmaceutical ingredients (APIs), and other compounds utilized in manufacture, are present in these wastewaters (Chandak et al., 2020). The production procedures used in pharmaceuticals vary greatly based on the particular medication being manufactured. The life cycle approach considers the environmental impact of a process or product at each phase of its entire lifespan, from raw material exploitation to manufacturing to use, transportation, as well as disposal (Rehman et al., 2013). This technique covers the whole life cycle of a med-

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