ISSN: 2582-8118 ***Volume 4, Issue 4; July 2024***

INTERNATIONAL JOURNAL OF RESEARCH AND ANALYSIS IN SCIENCE AND ENGINEERING

Web: https://www.iarj.in/index.php/ijrase/index

2. Emerging Trends in Biological Wastewater Treatment

Manju

Research scholar, SGV University,
Jaipur, Rajasthan.

Prashant Singh

Research Associate, Agro Synthesis,
Research and Development Center, CTG, SRF LTD.,
Bhiwadi, Alwar, Rajasthan.

Gaytri Jonwal, Ankit Yadav,
Bhavana Sharma

Dept. of Chemistry,
Agrawal PG College Jaipur, Rajasthan.

Dr. R. C. Chhipa

SGV University Jaipur, Rajasthan.

ABSTRACT

Applying sustainable and circularity approaches to biological wastewater treatment offers several opportunities. In order to eliminate or recover nutrients and organic contaminants from a wide range of wastewater types, biological wastewater treatment is frequently utilized. Conventional biological processes, however, have drawbacks such poor efficiency, excessive energy use, and excess sludge formation. Integrated solutions that combine biological treatment with other physical, chemical, or biological treatments have been developed and implemented recently in an effort to overcome these constraints. With an emphasis on their mechanisms, advantages, difficulties, and future prospects, this review highlights the most recent developments in integrated techniques for biological wastewater treatment. The review delves into the possible uses of integrated approaches for treating heterogeneous wastewater in the context of low-carbon fuel production, resource recovery, and green energy generation. The following biological treatment techniques are outlined in relation to metabolic reactions that are not genetically modified: bioremediation, electro-coagulation, electro-flocculation, electro-Fenton, advanced oxidation, electro-oxidation, bio-electrochemical systems, and photo-remediation.

Different conducting materials (CMs) help to increase fermentation rates and are important in metabolic processes involving mass/charge transfer. Fermentative biocatalysts are given favorable conditions and prompted to act in order to overcome the constraints of the conventional process through the hybridization of carbon, metal, and nano-based CMs in various processes.

KEYWORDS:

Biological Wastewater Treatment, Microalgal wastewater treatment (MWWT), Advanced Oxidation Processes (AOPs), Membrane technology (MT), Wastewater treatment.

Introduction:

Construction, hydromechanical, electrical, monitoring, and automation equipment make up the complex systems that make up wastewater treatment plants. Simple systems are less expensive to invest in and operate, yet they can become unstable when operational conditions change and generate sensitive processes. Complex installations that are adequately monitored highlight how dynamic the processes are and how the effluent quality varies greatly at the treatment plant's entry point.By minimizing the negative effects of wastewater discharge on the environment, recovering valuable resources from wastewater, and creating bioproducts and renewable energy, biological wastewater treatment techniques can support green energy and environmental sustainability. The high capital and operating expenses, the reactors' unstable performance and scalability, the products' quality and safety, and societal and regulatory restrictions are some of the limitations and challenges that must be overcome. Mutual synergism between the metabolic processes of microorganisms that are unable to separately catabolize their metabolites is known as biological syntropy. One type of syntrophic process known as interspecies electron transfer (IET) occurs when free electrons move from one cell to another via common electrical and physical connections. The type and sensitivity of the biocatalyst, the composition of the substrate, low productivity or yields, product creation, feedback inhibition, product purity, etc. are all factors that affect the bioprocess efficiency. By using materials, electrodes, microbes, or syntrophic regulation, metabolic constraints can be overcome. Unbalanced microbial metabolism is the process that results in the formation of an oxidized product when the electrode acts as the electron acceptor (intermediate). [1][2]

Contaminants in Wastewater:

Water that has been contaminated primarily by human activity is referred to as wastewater. It comes from a variety of sources, including storm runoff, infiltration, and residential, commercial, and agricultural activities. The majority of wastewater is composed of solids and water. Since each wastewater treatment facility is designed with these factors in mind, the chemical composition and flow conditions typically dictate the characteristics of wastewater. Storm runoffs primarily enter during the wet season, when wastewater flow conditions are determined by the seasons. The chemical quality of wastewater is determined by looking at its organic and inorganic components. When assessing the chemical properties of wastewater, the following factors are typically taken into account: total nitrogen (TN), total solids (TS), metals, and biochemical oxygen demand (BOD).

Total nitrogen and phosphorus:

These are plant nutrients found in wastewater as either nitrates or ammonia; the agricultural and corrosion inhibitor industries, as well as fertilizer production enterprises, typically produce them. Total nitrogen in wastewater is made up of ammonia, organic and inorganic nitrogen, including nitrate, nitrite, and ammonium as well as organic dissolved molecules such urea, amino acids, and organic nitrogen composites. Phosphorus can also be found in aquatic environments as phosphates, including orthophosphates, condensed phosphates, and phosphates that are organically bonded. [3]

Wastewater containing phosphate and nitrogen causes eutrophication in water bodies, which, if released untreated, can kill aquatic habitats. High rates of nitrogen and phosphorus removal have been attained by the use of a microalgae treatment method; reports of its industrial application have indicated removal rates of between and. [4]

Biochemical oxygen demand (BOD):

This is the amount of oxygen needed by bacteria in aerobic circumstances to break down organic materials. Similar to COD, BOD influences the amount of dissolved oxygen needed by aquatic species and, if it is less than mg/L, may cause their demise. It also indicates the extent of contamination. Domestic wastewater with trace amounts of industrial effluent typically has a BOD value of mg/L, mg/L, and mg/L for low, medium, and high strength wastewater, respectively.

Total solid (TS):

This is wastewater's content of organic and inorganic materials, suspended and dissolved solids, and volatile and settleable solids. Even though the majority of suspended particles are readily removed by physical separation techniques, some nevertheless manage to enter the environment. Various treatment processes take into account the quantity of volatile solids removed from wastewater, since the dissolved and volatile solid (VS) contents serve as an indicator of the wastewater's degradable content. The strength of wastewater is also indicated by its VS content, where a greater VS value corresponds to a stronger wastewater and vice versa.

Metals:

Wastewater from the manufacturing, mining, and textile industries is typically contaminated with metals. Common contaminants found in industrial wastewaters include arsenic, iron, chromium, lead, copper, tin, sodium, potassium, mercury, aluminum, and nickel. Because metals do not biodegrade and some do accumulate over time, even low concentrations of metals (mg/L) in wastewater are harmful. While some metals, like copper, zinc, and chromium, which are necessary for humans, animals, and plants, may still be tolerated in trace amounts, excess of these metals can be harmful. [5]

Emerging Trends in Wastewater Treatment Technologies:

The legislation and heavy fines associated with wastewater disposal that exceed specified discharge limits are major factors that have sparked the development of new or better wastewater treatment technology. The financial stability of factories and industries has been negatively impacted, which has led to the development of new or enhanced treatment solutions. Due to their affordability and environmental friendliness, anaerobic and aerobic methods have gained popularity recently for the treatment of organic wastes. However, because they need less energy than other technologies, anaerobic technologies are superior.

The type of technology that is used is mostly determined by the characteristics of the wastewater, so it is important to describe streams in order to identify important wastewater properties like COD, TS, VS, and salt content, among others. This chapter’s core idea is based on three cutting-edge technologies: membrane, microalgal, and microbial fuel cell (MFC) technologies. These technologies can be used as a therapy mechanism singly or in combination.

Membrane technology (MT):

The related scientific and engineering techniques for the movement of materials, species, or components across or across membranes are referred to as "membrane technology" (MT). Usually, the mechanical processes involved in separating liquid or gas streams are described using this manner. One kind of thin-layer barrier utilized in size differential separation is a membrane. Usually, chemical and biological treatments are employed in concert with them. They could, nevertheless, be applied separately in the subsequent treatment of wastewater.

Advanced Oxidation Processes (AOPs):

Chemically based advanced oxidation processes (AOPs) are widely employed as primary procedures in wastewater treatment. However, these processes are not only economically unfeasible when used as individual primary or secondary units, but they also have numerous limitations in that they require proportionate amounts of hydroxyl radicals and chemical reagents based on the presence of the wastewater pollutants to be scavenged. As a result, the process is not practical for handling large volumes of wastewater. Within this framework, advanced AOP methods combined with other processes have become increasingly important. Examples of these include electro- and Photo-Fenton processes, electrochemical oxidation, electro-flocculation, electro-flotation, photo- and electro-catalytic materials in combination with UV systems (TiO2/UV or H2O2/UV), etc. By using a step-wise approach, these advanced integrative processes have the potential to improve cumulative wastewater treatment while using less chemicals and reagents and costing less for operational viability as compared to traditional AOPs. [6]

Microalgal wastewater treatment (MWWT):

Water-security is a viewpoint that characterizes the consistent availability of a sufficient amount and quality of water for productivity, livelihoods, and health, along with a manageable degree of risk associated with water.

But the dynamics of population growth and the spread of industrial facilities have created an imbalance in the water-resource equation. The amount of water that is needed for domestic use, the production sector of the economy, commercial services, and agriculture have all exceeded the amount of potable water sources that can meet demand. Serious issues with society, health, and the environment are brought on by some of these sources' unethical wastewater disposal. Additionally, due to insufficient precipitation and limited capacity for rainwater harvesting, freshwater-scarce countries are increasingly in need of promoting water reuse technologies in an effort to reduce the dumping of effluent wastewater. Energy and chemical input requirements for operating functional wastewater treatment plants (WWTP) for municipalities throughout the world have proven to be very high. Even though primary, secondary, and tertiary are the basic stages of treatment, these facilities' effluent contributes to secondary pollution because it doesn't fulfill the green-drop requirements. [7]

Microbial fuel cells for wastewater treatment:

To create a sustainable foundation for the future, civilization must significantly lessen its need on fossil fuels. The extent of pollution on a worldwide scale can then be reduced by this reduction. Wastewater, sometimes known as waste matter, has seen a paradigm shift in recent years as enterprises are now using it to generate power. Studies have specifically shown that a variety of biological processing techniques can be applied to cleanse industrial wastewater and produce bioenergy or bio-chemicals. Microbial fuel cells (MFCs) have been specifically emphasized for use in the treatment of brewery effluent [8].

Review of Literature:

Research by Suad Jaffer Al-Lawatietal Diverse technological, social, and economic settings surround the treatment of wastewater and the creation of sludge, calling for a range of strategies and solutions. Most of the time, in order to treat wastewater and manage sludge in an environmentally responsible manner, regular laws and treatment plans that are specific to the area must be developed. The primary objective of their study is to offer useful information regarding the current management, analysis, law, and wastewater and sludge treatments in Oman.

Studying with Jayashree Dhoteet Many water resources are currently contaminated by man-made sources, such as industrial processes, home and agricultural waste, and water pollution. Concerns among the public about the effects of waste water pollution on the environment grew. Many conventional wastewater treatment techniques have been utilized to remove the contaminants, including chemical coagulation, adsorption, and activated sludge. Despite this, there are still certain limitations, especially with regard to high operating costs. As a reductive medium, aerobic waste water treatment is becoming more and more popular due to its low operating and maintenance costs. [9]

The United States has a well-established wastewater infrastructure, with centralized treatment plants widely distributed throughout urban and industrial areas, according to Sharma et al., 2023. Federal and state financing, initiatives from the commercial sector, and research institutes are the main drivers of investment in advanced technologies including membrane bioreactors and improved oxidation processes.

Innovative culture encourages ongoing development, and strong infrastructure makes it possible to incorporate state-of-the-art technologies. On the other hand, many African countries struggle with a lack of proper wastewater infrastructure, especially in periurban and rural areas. Financial constraints prevent large-scale investments in cutting-edge technologies. Decentralized strategies and locally specific natural solutions, on the other hand, present potential. Overcoming infrastructure obstacles and realizing the potential of sustainable wastewater treatment can be accomplished through international collaborations, capacity-building initiatives, and focused investments. [10]

Mondejar et al., The landscape of wastewater treatment is changing, with new developments and technologies coming into play. In order to improve process efficiency and real-time monitoring, advanced wastewater treatment processes will probably see more integration with digital technology, such as artificial intelligence and machine learning. In line with the objectives of global sustainability, decentralized treatment systems, smart sensor networks, and the use of renewable energy sources are anticipated to proliferate. [11]

Zahra Aghalarietal gathered information based on the inclusion and exclusion criteria as well as by looking up relevant keywords in publications published between 2008 and 2018 with an emphasis on how successfully waste water treatment systems remove bacterial agents. Preferred reporting items for the systematic evaluations and meta analyses (PRISMA) standards checklists were used to gather qualitative data. Information was added into the checklist after the accuracy of the articles was confirmed, including the initial author's name, the year the report was published, the types of analysis, sample numbers, purification technique, types of microbiological agents, and rates of microbial agent removal. Furthermore, the study compared the clearance rate of the microbial agent with the standard set by the United States Environmental Protection Agency (USEPA).

In order to treat actual PW (from a Malaysian oilfield called Petronas) and synthetic PW (with additional crude oil and salts), Pendashteh et al. (2010) used a lab-scale (5L) SBR for 24 hour cycles (1 h feeding, 21 h reacting, and 1 h settling and decanting). A halophilic consortia of microorganisms enriched from saline soil polluted with oil was introduced into the reactor. When the TDS of synthetic PW was raised from 35,000 to 250,000 mg/L, COD elimination dropped from 93% to 63%. 83% COD elimination was attained when actual PW (TDS: about 16,500 mg/L, COD: 1,240 mg/L) was supplied after adaptation to synthetic PW. A Biolog Microlog System was used to identify the main bacterial groups found in the reactor sludge, which included Pseudomonas, Ochrobactrum, Corynebacterium, and Burkholderia. [12]

Objectives:

1. To study of technologies of wastewater treatment.
2. To analysis of biological Wastewater Treatment by using Nitrogen removal technologies.
3. To study of emerging trends in global market.

Research Methodology:

The overall design of this study was exploratory. The research paper is an effort that is based on secondary data that was gathered from credible publications, the internet, articles, textbooks, and newspapers.

Result and Discussion:

The advancements in waste/wastewater treatment are discussed in detail in this review in order to address new contaminants and achieve low-carbon energy and resource recovery. Figure 1 summarizes biological treatment techniques in relation to non-genetically modified metabolic reactions. These techniques include bioremediation, electrocoagulation, electro-flocculation, electro-Fenton, advanced oxidation, electro-oxidation, bio electrochemical systems, and photo-remediation. The constraints and difficulties with advanced treatment techniques that need to be resolved in order to make them more economically and energetically viable are highlighted in particular. Included are sustainable integrations with other treatment procedures that might be in line with a biorefinery approach's circular economy viewpoint. [13]

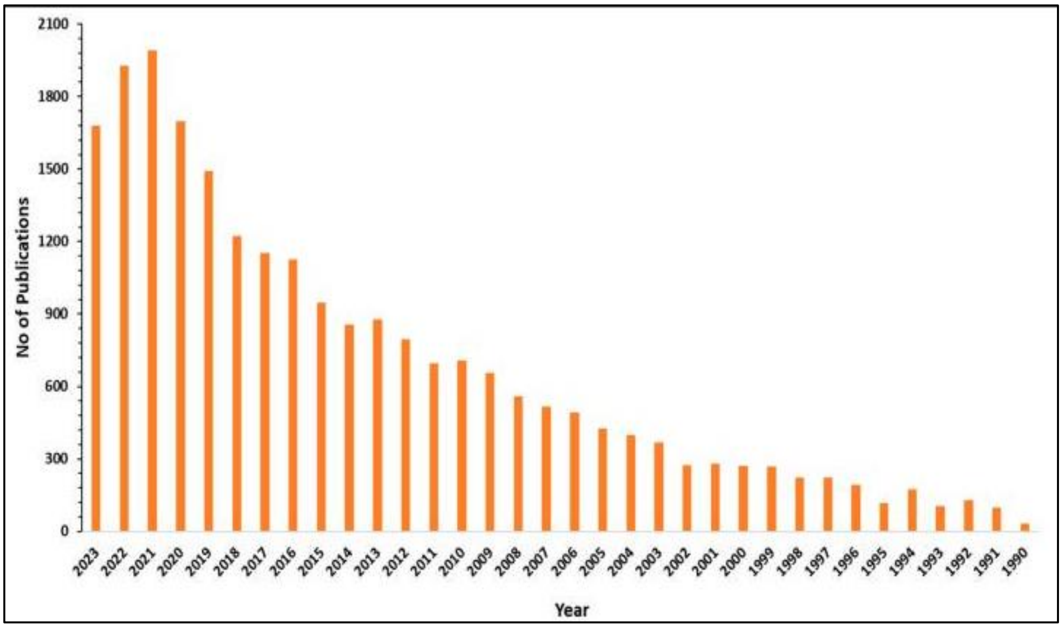

Figure 3.1: Biological wastewater treatment methods

Nitrogen removal technologies were introduced in this rising trend of biological wastewater treatment, leading to a decrease in the amount of nitrogen loads discharged into the Baltic Sea.

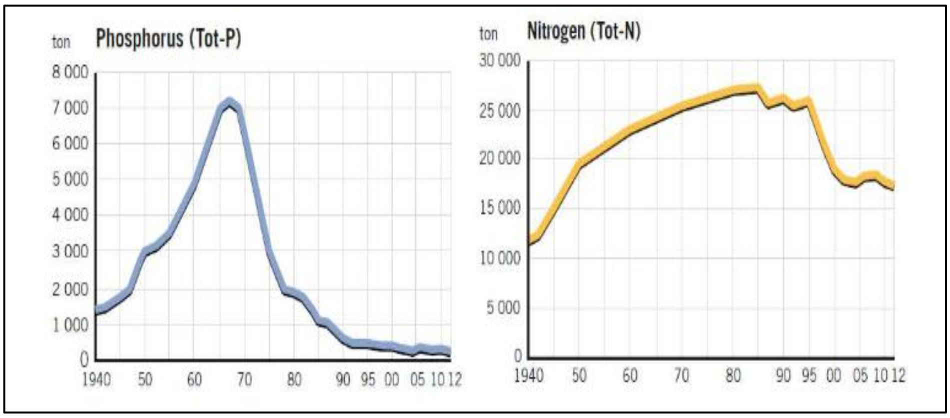

Figure 3.2: Phosphorus and nitrogen discharges from wastewater treatment plants into the Baltic Sea

In order to lessen the amount of nitrogen and phosphorus that are released into the Baltic Sea, Figure 2 illustrates how wastewater treatment plants are getting ready for tighter regulations on these two nutrients' removals. Treatment facilities that do not remove nitrogen will remove 70% of the nitrogen; those that do will remove 80% of the nitrogen by adding more external organic material and increasing wastewater recirculation after the nitrification process. Upon completion, the treatment facilities will have 6 mg/L of total nitrogen at the outlet. Treatment plants' output is measured at 0.2 mg P/L and 0.1 mg P/L, respectively. [14]

Global Biological Wastewater Treatment Market Analysis:

The market for biological wastewater treatment is expanding due to a number of factors, such as the population's rapid growth and urbanization, the water treatment regulations that are driving up the demand for new water resources because public health and water quality are becoming more important, and the rise in waterborne disease incidence. Additionally, given the growing need for advanced and energy-efficient water treatment technologies, companies that provide wastewater and water treatment systems are expected to see significant growth opportunities in the years to come.

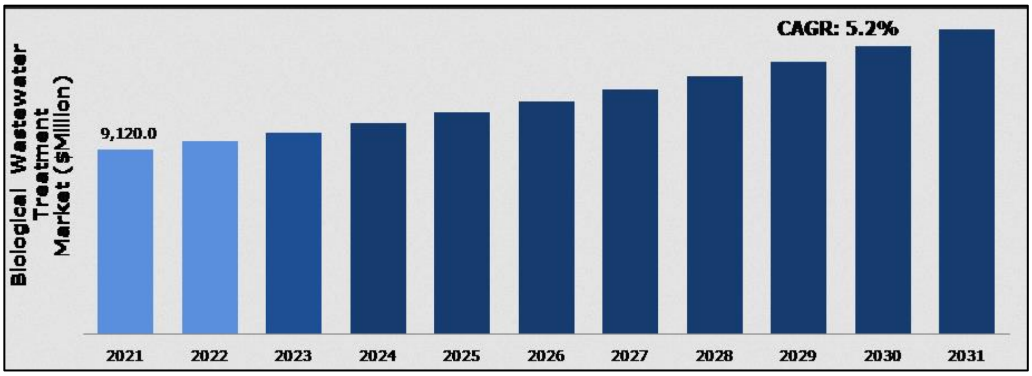

Figure 3.3: Global Biological Wastewater Treatment Market Analysis

Figure 3's regional analysis indicates that the size of the Asia-Pacific biological wastewater treatment market was $2,9,120 million in 2021 and is expected to increase at a compound annual growth rate (CAGR) of 5.2% during the estimated period. This is a result of China's increased focus on and efforts to lower the high levels of environmental pollution in the country. The size of the global biological wastewater treatment market was $9,120.0 million in 2021, and it is expected to increase at a compound annual growth rate (CAGR) of 5.2% to reach $15,067.7 million in revenue by 2031. [15]

Conclusion:

Currently, one of the frontiers of wastewater treatment research is biological wastewater treatment. No matter how advanced and durable the treatment procedure is, some hazardous substances may still be present in the treated sewage. One of the scarcest natural resources at the moment is water, which was formerly thought to be the most plentiful. Recent improvements in wastewater treatment techniques point to promising advancements in treatment system development in the near future. Nevertheless, a wide range of pathogens are found in wastewater. The socioeconomic circumstances and cultural practices of the communities producing the wastewater have a significant impact on the quantity and kinds of these pathogens that are present. Understanding the dangerous environmental effects that untreated or insufficiently treated wastewater poses to the surrounding ecosystems is crucial. Given the above-mentioned facts, it is the responsibility of environmental scientists worldwide to seek the development of highly effective and affordable wastewater treatment techniques in order to guarantee safe wastewater treatment for the benefit of humankind.

References:

1. Prevoteau A., Carvajal-Arroyo J.M., Ganigue R., Rabaey K. Microbial Electrosynthesis from CO2: Forever a Promise? Curr. Opin. Biotechnol. 2020; 62:48–57. doi: 10.1016/j.copbio.2019.08.014.
2. Sharma M., Alvarez-Gallego Y., Achouak W., Pant D., Sarma P.M., Dominguez-Benetton X. Electrode Material Properties for Designing Effective Microbial Electrosynthesis Systems. J. Mater. Chem. A. refences: A. 2019
3. Canada H. Total Dissolved Solids (TDS)
4. Islam MMM, Shafi S, Bandh SA, Shameem N. Impact of environmental changes and human activities on bacterial diversity of lakes. Fresh w Microbiol perspect Bact Dyn Lake Ecosyst
5. Baysal A, Ozbek N, Akm S. Determination of Trace Metals in Waste Water and Their Removal Processes. Waste Water - Treat Technol Recent Anal Dev [Internet].
6. Sershen, Rodda N, Stenström TA, Schmidt S, Dent M, Bux F, et al. Water security in South Africa: Perceptions on public expectations and municipal obligations, governance and water re-use. Water SA [Internet]. South African Water Research Commission; [cited Aug 14]
7. Logan BE, Hamelers B, Rozendal R, Schröder U, Keller J, Freguia S, et al. Microbial fuel cells: methodology and technology. Environ Sci Technol.
8. B. S. Choudry, “Ac ce pt cr t,” vol. 2247, no. October, 2016, doi: 10.1080/10962247.2016.1243595.
9. T. W. Seow et al., “REVIEW ON WASTEWATER TREATMENT TECHNOLOGIES Jayashree Dhote,” Int. J. Eng. Res. Technol., vol. 1, no. 5, pp. 1–10, 2012.

10. Sharma, B. M., Scheringer, M., Chakraborty, P., Bharat, G. K., Steindal, E. H., Trasande, L., & Nizzetto, L. (2023). Unlocking India’s potential in managing endocrine-disrupting chemicals (EDCs): importance, challenges, and opportunities. Exposure and Health, 15(4), 841-855
11. Mondejar, M. E., Avtar, R., Diaz, H. L. B., Dubey, R. K., Esteban, J., Gómez-Morales, A., . . . Prasad, K. A. (2021). Digitalization to achieve sustainable development goals: Steps towards a Smart Green Planet. Science of the Total Environment, 794, 148539
12. Pendashteh, A. R., Fakhru’L-Razi, A., Chuah, T. G., Radiah, A. B. D., Madaeni, S. S., and Zurina, Z. A. (2010). Biological treatment of produced water in a sequencing batch reactor by a consortium of isolated halophilic microorganisms. Environ. Technol. 31, 1229–1239
13. Muduli M., Chanchpara A., Choudhary M., Saravaia H., Haldar S., Ray S. Critical Review on Sustainable Bioreactors for Wastewater Treatment and Water Reuse. Sustain. Water Resource. Manag. 2022; 8:159. doi: 10.1007/s40899-022-00747-5.
14. Wastewater treatment in Sweden. Report Swedish EPA, ISBN 978-91-620-8416-5 (2016)
15. https://www.researchdive.com/163/biological-wastewater-treatment-market