Wastewater Reuse and Resource Recovery for Exemplifying Sustainable Development

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Abstract

The Availability of fresh water is very limited and it is further getting contaminated due to anthropogenic activities. As a result, the treatment of contaminated water or wastewater has gained considerable attention in the recent past so that the water bodies can be prevented from contamination arising due to the discharge of wastewater into them. However, in the longer run, the treatment of wastewater just to meet the discharge standards is not sufficient to solve the issue of water scarcity. Therefore, it is very important to socially and scientifically encourage the idea of wastewater reuse, where it can be used as the feedstock for resource recovery like the production of bioelectricity, biofuels, biofertilizers, bioplastic, commodity chemicals and many more. Recovering energy as biofuels or other valuable products from wastewater will reduce the dependence on renewable sources, minimize the direct and indirect carbon dioxide emissions to the environment, and thus will assist in the attainment of Sustainable Development Goals set by the United Nations.

Keywords: Biofuel • Carbon sequestration • Resource recovery • Sustainability • Wastewater Reuse

Introduction

In the last few decades, a rise in the intensity and frequency of extreme weather conditions such as heat waves, excessive precipitation, and wildfires have been observed, which are majorly attributed to anthropogenic activities. Extreme weather events are rooted in increasing average global temperature causing diminution of water sources, combined with the increased demand for anthropogenic uses, further increasing the existing stress on water bodies. As a result, mankind is striving for alternate renewable energy sources instead of fossil fuels because of the ill effects like climate change and global warming associated with non-renewable sources of energy. Therefore, now it is highly desirable to shift the focus to the use of clean, green and renewable energy sources and one such source is wastewater, as it possesses high energy in the form of organic matter.

In this veneration, the most visible example of wastewater treatment and reuse is NEWater, produced by the Singapore public utility board. The wastewater generated in the city goes through a two-stage process consisting of water reclamation plants and NEWater plants before being reused. The water reclamation plants are a combination of lamella clarifier and membrane bioreactor, whereas the NEWater plants are advanced treatment units consisting of micro/ultrafiltration, reverse osmosis and ultraviolet disinfection. Currently, five such plants are satisfying 40% of Singapore's water demand, which turnout out to be around 285 billion litres per year.

On the other hand, numerous other technologies are also available that can be employed to recover valuables like bioenergy from the wastewater, such as Bio-Electrochemical Systems (BES), microalgal technology, upflow anaerobic sludge blanket etc. Recently, microalgal technology has grabbed a lot of attention for the treatment of wastewater because it has the ability to exhibit carbon sequestration. During photosynthesis, algae consume carbon in the form of HCO_3^- rather than CO_3^{2-} ions causing the pH of the wastewater to increase to around 10, which further increases the scope of CO_2 dissolution in water to form carbonic acid. This algae-based technology is also very efficient in the removal of nutrients such as nitrogen, phosphorus, and even heavy metals from wastewater and is highly adaptive as microalgal strains can be genetically modified to synthesize other microalgal consortiums as per the wastewater characteristics. In this regard, different microalgae such as *Chlorella sorokiniana*, *Dunaliella salina*, *Ellipsoidion sp*., *Scenedesmus sp*. *DM*, etc., can be effectively employed for resource recovery from wastewater and the biomass produced in the process can be effectively used to produce a variety of valuable products such as biofuels, biofertilizers, biogas, and bioplastic. Algal biomass of *Chlamydomonas reinhardtii*, *Nannochloropsis*, *Spirulina*, and *Scenedesmus* can be used to derive biopolymers such as polyhydroxyalkanoates, polysaccharides, etc., which can be used as raw material for the production of bioplastics thus, reducing the burden on the environment associated with the use of non-biodegradable plastics. Similarly, cyanobacteria that are more resistant to extreme weather conditions and have low maintenance cost compared to heterotrophic bacteria can also be used for resource recovery from wastewater. Further, the biomass derived from cyanobacteria sequestering CO_2 can also be used as feedstock for energy generation, such as biodiesel production from lipids, bioethanol generation from carbohydrates, and biofertilizers. Moreover, wastewater can also be used as a substrate for culturing yeast and fungi, which can be harvested to produce biodiesel or biethanol from the lipids stored in them.

Apart from the discussed technologies, wastewater also has the potential to act as a substrate for biohydrogen production by employing methods like dark fermentation, photo fermentation, microbial electrolysis, etc. Microorganisms used for wastewater treatment are probably one of the most crucial factors apart from selecting an efficient bioreactor for hydrogen production. In this regard, there are multiple bacteria species under the umbrella of a different genus, such as *Clostridium*, *Enterobacter*, *Bacillus*, *Escherichia*, *Klebsiella*, etc., which are capable of hydrogen production from substrates like glucose, xylose, wastewater, etc. thus, choosing the correct species is essential. Further, the by-products of the anaerobic techniques, such as dark fermentation, can be directly utilized as substrate in processes like the microbial electrochemical cell to enhance the further recovery of hydrogen and methane.

Conclusion

The way wastewater is perceived in value has changed significantly in the last few decades, from being inoperable to becoming a valuable resource. This paradigm shift in perception around wastewater empowers the researchers to work towards reclaiming the used water and concomitantly recovering resources. New technologies such as hybrid systems combining primary treatment with membrane technology can provide high-quality treated water fit for reuse, as achieved by NEWater. Likewise, the carbon present in wastewater can be consumed by microorganisms such as microalgae, cyanobacteria, etc., to produce biofuels, bioelectricity, and other valuable products through innovative technologies like microalgal technology, dark fermentation, photo fermentation, BES, or hybrid systems. These methods not only hold the potential to serve as a consistent water source but also generate valuable resources like biofuels, thus reducing the carbon footprint arising from wastewater treatment, which is of great importance, especially to counter climate change leading to extreme weather conditions.

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