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Energy Requirement of Wastewater Treatment Plants: Unleashing the Potential of Microalgae, Biogas and Solar Power for Sustainable Development

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ABSTRACT

Sustainable energy legislation in the modern world is the primary strategy that has raised the benchmark for energy and environmental security globally. The rapid growth in the human population has led to rising energy needs, which are predicted to increase by at least 50% by 2030. Waste management and environmental pollution present the biggest challenge to developing countries. The improvement of energy efficiency while ensuring higher nutritional evacuation wastewater treatment plants (WWTPs) is a significant problem for many wastewater treatment plants. Some treatment techniques require high energy input, which makes them expensive to remediate water use. Pollutants like chemical pesticides, hydrocarbons, colorants (dyes), surfactants, and aromatic compounds are present in wastewater and are contributing to other problems. Israel consumes 10% of the global energy supply, significantly more than other countries. The lagoon and trickling filters are the most widely used technologies in South African WWTPs, where the electricity intensity ranges from 0.079 to 0.41 $kWh.m^{-3}$ (Wang et al. 2016). Korea and India use almost the same energy (0.24 $kWh.m^{-3}$). An estimated one-fifth of the energy used in a municipality's WWTPs is used for overall public utilities, and this percentage is anticipated to rise by 20% over the next 15 years owing to expanding consumption of water and higher standards. In this review paper, we examined the potential for creating energy-self-sufficient WWTPs and discussed how much energy is currently consumed by WWTPs. The desirable qualities of microalgae, their production on a global level, technologies for treating wastewater with biogas and solar power, its developments, and issues for sustainable development are highlighted. The scientific elaboration of the mechanisms used for pollutant degradation using solar energy, as well as their viability, are the key issues that have been addressed.

INTRODUCTION

The primary strategy that has raised the standard of energy and environmental security globally is sustainable energy legislation in the present world. The enhancement of the energy effectiveness of the current facilities is one of its pillars. The infrastructure for water and sewage systems in cities is the biggest consumer of electricity, accounting for as much as %40 of total consumption. The whole water management industry accounts for %4 of the power usage in the globe. The actions intended to improve resource efficiency in the industry are needed because of the rising wastewater production and water demand. Global nutrient requirements, as well as water and energy restoration from wastewater, are currently the main forces driving the development of the wastewater industry. Due to the inclusion of energy generation and resource rehabilitation during the manufacture of safe and clean water, urban wastewater treatment plants can be a significant component of circular sustainability.

It is significant to note that electricity accounts for 20% of the expenditures associated with the supply and treatment of water supply and sometimes even up to 40% of the operating budget of water business units (Di Fraia et al. 2018). Furthermore, it is anticipated that municipal water supply mechanisms will use an additional 60–100% more energy in the coming 15 years (Masłoń et al. 2018). Global nutrient requirements, as well as water and energy restoration from wastewater, are currently the main forces driving the development of the wastewater industry (Neczaj & Grosser 2018). The near future will see the development of "ecologically sustainable" technological systems for WWTPs. However, over the past 25 years, many significant forces have highlighted the necessity of recovering the resources present in wastewater.

Rising energy needs are a result of the quick increase in the human population, and by 2030 those needs are expected to rise by at least 50%. Natural petroleum is unable to keep up with the current rate of consumption, which is already 105 times faster than what nature can produce. Additionally, the use of fossil fuels harms our environment by emitting greenhouse gases, which contribute to global warming. Thus, finding "clean" energy has become one of the most difficult tasks. Several alternatives are being researched and used right now. Biofuels, or fuels derived from living organisms, are advantageous for the environment because they reduce harmful CO_2 and hydrocarbon emissions and eliminate SOx emissions, which reduces the greenhouse effects.

The primary obstacle to developing nations comes from the management of waste and environmental contamination. A major issue for numerous wastewater treatment plants is the advancement of energy efficiency while ensuring higher nutritional evacuation (WWTPs). Water bodies are disturbed, and surface and groundwater are contaminated as a consequence of poor treatment and the release of industrial contaminants into the environment. According to estimates from the World Health Organization (WHO), 1.8 billion people do not have adequate drinking water that is safe to consume. The amount of drinkable water that is readily available for direct utilization is less than 1% of the total water capacity. According to the United Nations and other nations, having access to safe, clean water is a human right of fundamental importance (Pandey et al. 2021).

Energy from the sun's interfacial evaporation is a process used in desalinated water, treatment of wastewater, generation of electricity, and residential water heating systems as a reliable way to capture solar energy and remove the soluble pollutants in water (Gao et al. 2019, Geng et al. 2019). Interfacial evaporation of solar energy occurs when sunlight's thermal energy is transferred to water molecules at the air-water interface, where it continuously evaporates into steam (Tao et al. 2018, Li et al. 2019). The Electricity Regulatory Commission Act of 1998 developed the Regulatory Commissions to promote innovation in the electricity sector by fostering competitive pressure, boosting efficiency, and promoting economic growth in the electricity industry. India is also at the forefront of economic growth by focusing on the change in the power sector (Sharma et al. 2012). Our attention has been focused on using renewable energy as a source of energy that is environmentally friendly due to the alarming challenge of a growing population and depleting natural resources. The addition of renewable energy to the energy mix would reduce the system's reliance on the grid connection, increase system reliability in terms of efficiency, and reduce carbon emissions (Singh 2016).

There has been a lot of interest in photothermal materials with high energy conversion and broad solar absorption nowadays. They are quickly expanding as a research area of interest in the generation of clean water by solar-driven vaporization. The eco-sustainable water vaporization technology powered by solar energy has attracted interest as a long-term remedy for the shortage of water (Gao et al. 2019). In this review paper, we investigated the possibility of developing energy-self-sufficient WWTPs and talked about the energy consumption of WWTPs today. The advantages of microalgae, their production on a global scale, biogas and solar energy technologies for wastewater treatment, as well as their advancements and concerns for sustainable development, are highlighted. The key issues have been addressed, including the scientific development of the processes used for the degradation of pollutants using solar energy and their viability.

WASTEWATER TREATMENT PLANTS (WWTPS)

Wastewater treatment plants (WWTPs) are a necessary component of a local government framework. To transport wastewater, carry out technological processes, and run office equipment, these facilities need to be supplied with a sizable amount of electricity (Di Fraia et al. 2018). An important portion of an object's operational costs, in particular, go towards ensuring the continued viability of industrial applications (Roots et al. 2020). Consequently, there continues to be a demand for solutions to increase the efficacy of both thermal and electrical energy production and recovery at WWTPs. Because of this, cutting-edge technologies for wastewater treatment that rely on embedded methods, such as the Anammox process (Wang et al. 2019) or agglomerated activated sludge (Czarnota et al. 2020) for nitrogen extraction, are being developed. The water resource has been heavily polluted by inorganic compounds, organic, as well as other harmful emissions as a result of rapid industrialization. When compared to more traditional alternative technologies, these systems are distinguished by their lower energy consumption. Additionally, different

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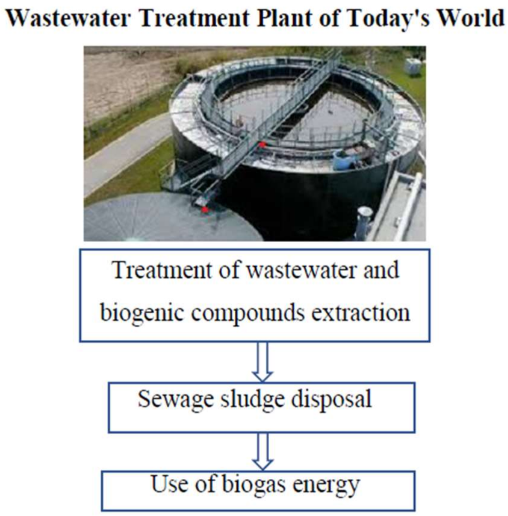


Fig. 1: Wastewater system (Neczaj & Grosser 2018).

aeration system operational and control strategies are used, as well as energy consumption optimization using a sophisticated, fully automated system for collecting data, simulation, and prediction (Drewnowsk 2019, Szeląg 2020).

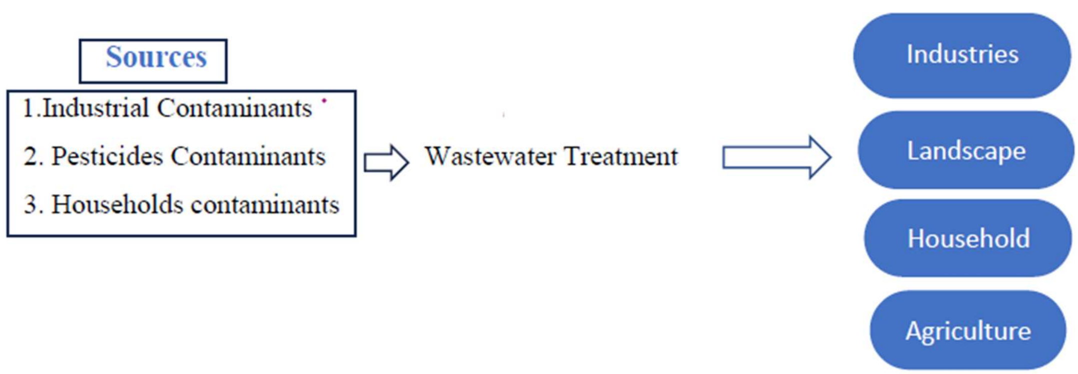
WWTPs are gradually becoming a key hub for SMART cities. Fig. 1 depicts the idea of an intelligent wastewater system in which WWTPs produce energy and fertilizer in addition to treating wastewater effectively enough to allow for effluent reuse. Around the world, more and more cities are putting SMART ideas into practice. The City of Bors in Sweden, for instance, has developed a project in which the local power plant and the WWTP will coexist, and the WWTP will provide renewable fuel for the city power plant (Swedish Utility Selects Veolia for Wastewater to Energy Project (Metering 2018).

The demand for freshwater at this time has exponentially increased. In India, Pakistan, and other parts of the world, there is a critical need for fresh water. The amount of water used in manufacturing has greatly increased over the past few years. Water shortages are a result of corporate water use (Sharshir et al. 2020). This phenomenon aims to treat regenerative/non-biodegradable wastewater that cannot be adequately treated using industrially common biological and medicinal processes. To enhance the efficacy of contaminant oxidation that exists in wastewater and maintain economic growth, untreated pharmaceutical industry effluent was oxidized using a heterogeneous photo-catalytic method (Haddeland et al. 2014).

Freshwater availability is now the main concern for contemporary society. The process of treating wastewater that has been adulterated by business and manufacturing operations requires a lot of energy and relies on traditional energy sources. There is growing interest in solar energy as a potential solution for water treatment. The level of sophistication in solar-powered treatment of wastewater can range from basic Solar stills and Solar Water Disinfection (SODIS) to advanced Membrane distillation (MD), Multi-Stage Flash (MSF), and Reverse-osmosis (RO). The choice of these technologies depends greatly on the site. Solar still and SODIS are appropriate for tropical nations with plenty of solar energy but lacking resources and skilled labor (Sansaniwal 2022).

An organic semiconductor material called a photocatalyst possesses an established activity-level framework according to sound quantum theory (Bahnemann 2004).

The global issue of long-term energy and the decrease of freshwater can be resolved using solar energy, which is plentiful and accessible in many places. Researchers try their best to find various solutions to this issue. Since solar energy is a source of fresh water, numerous studies have been done to increase the effectiveness of solar desalination, evaporation, and wastewater treatment (Sharshir et al. 2020).



(Source: Pandey et al. 2021).

Fig. 2: Usage of solar energy in wastewater treatment.

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POLLUTANTS PRESENT IN WASTEWATER

Drinking water demand is rising quickly, along with population growth. The primary source of drinking water is increasingly being harmed by pollution discharge from the industrial sector as well as the agricultural sector (Agalit et al. 2020). These contaminants, even in small quantities, pose a serious threat to the ecosystem and public health. Therefore, before being discharged or put to other uses, the human pollutant needs to be effectively differentiated from water and wastewater. In addition to organic pollutants, synthetic pesticides, and industrial effluents are now significant contributors to wastewater contamination. Despite being discharged in small amounts, these effluents pose a serious threat to freshwater and marine species, seriously disrupting the ecological system.

The existence of pharmaceutical substances in aquatic environments may have an impact on equal biota as well as the health of humans because these micropollutants can change the metabolism and reproductive capabilities of the aquatic ecosystem's live organisms. These pollutants primarily enter the aquatic environment through the effluents of wastewater treatment plants (WWTPs). Diclofenac (DCF) and carbamazepine (CBZ) are two examples of substances that endure treatment with little to no degradation (Casierra-Martinez 2020).

Dye is a crucial chemical in many sectors, including manufacturing, food, furniture, and agriculture. In actuality, dumping dye pollutants into water has seriously harmed the environment and human health. Many researchers around the world are urged to create standard techniques for effectively treating dye wastewater employing solar energy (Haddeland et al. 2014). Traditional methods, such as microbial breakdown, coagulation, flocculation, adsorption on active carbon, adsorption filtration, and sewage, have been used to treat dye-polluted water. Endocrine disruptors, pesticides, industrial dyes, and other contaminants of the utmost importance are found in the environment.

Waste from domestic sources that consists of toxic materials is considered a household pollutant. Due to rising levels of pollution from municipal solid waste, household garbage is currently attracting more attention. It can be determined whether a household pollutant will have an adverse effect on the natural environment or human health by understanding how it gets from a home to a disposal facility. Waste from domestic sources that contain hazardous substances is considered a household pollutant. Due to rising levels of pollution from municipal solid waste, household waste has recently received more attention. Knowing how household pollutants are transported to disposal sites can help determine whether they have the potential to harm the environment or the health of humans (Pandey et al. 2021). A significant contributor to environmental pollution is the leather industry. Even after treatment at a Common Effluent Treatment Plant (CETP), the wastewater produced by the leather manufacturing sector has extremely high pollution-related parameters because of its containment of an intricate combination of inorganic and organic contaminants, which interferes with the ecological ecosystem (Yadav 2019).

Wastewater treatment plants should strive to maximize their energy efficiency. Rising energy prices emphasize the demand for energy self-sufficiency in WWTPs and worries about climate change. Studies on energy-self-sufficient WWTPs have been conducted to lower operating expenses, minimize energy use, and attain balancing of carbon.

ENERGY-SELF-SUFFICIENT WASTEWATER TREATMENT PLANTS

Wastewater treatment plants should strive to maximize their energy efficiency. Rising energy prices emphasize the demand for energy self-sufficiency in WWTPs and worries about climate change. Studies on energy-self-sufficient WWTPs have been conducted to lower operating expenses, minimize energy use, and attain balancing of carbon (Gu et al. 2017).

Wastewater treatment plants (WWTPs) must become energy self-sufficient if they are to sustainably meet the environmental regulatory requirements that are changing quickly. Only a small portion of WWTPs worldwide currently generate energy for useful purposes, and only a few of these facilities are energy-independent (Sarpong & Gude 2020).

There are typically three phases in a traditional municipal WWTP: primary, secondary, as well as advanced. The energy expenditure for collecting and pumping raw wastewater for primary treatment varies from 0.02 to 0.10 $kWh.m^{-3}$ in Canada, 0.04 to 0.14 $kWh.m^{-3}$ in Hungary, and 0.01 to 0.37 $kWh.m^{-3}$ in Australia (Pitas et al. 2010). According to reports, the average energy input for conventional activated sludge (CAS) treatment processes is 0.46 $kWh.m^{-3}$ in Australia, 0.26 $kWh.m^{-3}$ in China, 0.33 $kWh.m^{-3}$ to 0.60 $kWh.m^{-3}$ in the USA, and 0.30 $kWh.m^{-3}$ to 1.89 $kWh.m^{-3}$ in Japan (Bodik & Kubaska (2013)). The part of the wastewater treatment technology with the highest energy consumption is the aeration process in secondary treatment (Liu 2012). Most medium-sized and large WWTPs with CAS systems use between 50 and 60 percent of their total electricity for aeration, 15 to 25 percent for sludge treatment, and 15 percent for secondary sedimentation involving recirculation pumping systems (Mamais 2015). The reported average

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Table 1: Depicts energy distribution in standard activated sludge setups (Gu et al. 2017).

Conventional activated sludge system	Percentage Energy distribution
Chlorination, Return Sludge Pumping, and Thickening	1%
Clarifiers and Belt Press	3%
Lighting and buildings	6%
Anaerobic digestion	11%
Wastewater Pumping	12%
Aeration	60%

energy intensity in India was reported to be lower than that in the UK (0.46 $kWh.m^{-3}$) as a result of the support of low-energy technologies that utilize up-flow anaerobic sludge blanket (UASB) reactors or employ sunlight to generate heat for sludge drying in India. (Lee et al. 2017).

Table 1 and Fig. 3 display the outcomes of the overall distribution of energy in CAS systems. Because of the longer duration of hydraulic retention time (HRT) and greater consumption of electricity for a higher specific demand for oxygen, the oxidation ditch (OD) has a greater amount of energy demand compared to the CAS system of 0.5-1.0 $kWh.m^{-3}$ (Australia), 0.302 $kWh.m^{-3}$ (China), or 0.43-2.07 $kWh.m^{-3}$ (Japan) (Yang et al. 2010).

USAGE OF ENERGY OF WWTPS IN DIFFERENT LOCATIONS

Comparing the amount of energy used in WWTPs across the world is interesting and crucial. Table 1 displays the energy intensity proportion and national-level consumption of energy in WWTPs for various nations. With an average unit electrical use for WWTPs of 0.52 $kWh.m^{-3}$, the USA is a standard established nation. According to estimates, the USA's annual electricity consumption for wastewater treatment in 2008 made up 0.6% of the total (Wang et al. 2016). Asian nations exhibit a lesser energy strength for the treatment of wastewater in comparison to the USA. (China 0.31 $kWh.m^{-3}$, Japan 0.304 $kWh.m^{-3}$, in addition to Korea 0.243 $kWh.m^{-3}$) (Wang et al. 2016, Chae et al. 2013).

Energy is mainly regarded as a cost factor in wastewater design in India. The preparation for the supply of water and energy is not yet being done in a systematic, integrated manner. Saving energy in WWTPs is becoming more popular, especially for wastewater plants that have not yet been built. In Delhi, it is required of the electricity provider to maintain a steady supply to WWTPs, minimizing power outages. Newly constructed WWTPs must generate up to 60% of their electricity, typically through the production of combined heat and power biogas. Although Delhi has implemented a national feed-in tariff for biogas, none of

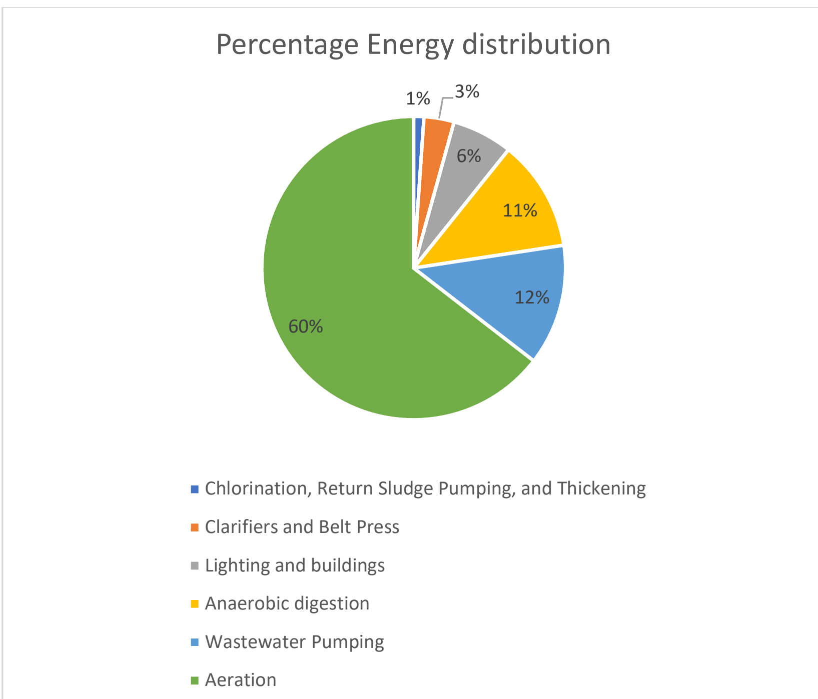

Fig. 3: Percentage of energy distribution in typical activated sludge systems.

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Table 2: National-level intensity of energy proportion and consumption in WWTPs in 44 countries.

Countries	Process and WWTPs	Energy intensity [$kWh.m^{-3}$]	Reference
Korea	Municipal WWTPs	0.243	Chae and Kang (2013)
India	Conventional Activated Sludge in Delhi	0.24	Never and Stepping (2018)
Germany	Average of 10,200 WWTPs	0.40-0.43	Wang et al. (2016)
Brazil	Conventional activated sludge system	0.24	Never and Stepping (2018)
Japan	Municipal WWTPs	0.304	Yang et al. (2010), Soares et al. (2017)
Sweden	Municipal WWTPs	0.42	Olsson (2012), Soares et al. (2017)
China	i) Humic filter ii) Aeration trench or anoxide-oxide system or rapid infiltration	0.31 0.4 – 0.5	Wang et al. 2016 Soares et al. 2017
South Africa	i) Lagoon treatment technology ii) Activated sludge	0.079-0.41 0.33–0.61	Wang et al. (2016
USA	i) Encina Water WPCF, CA ii) With chlorine disinfection in NYCDEP Owls Head WWTP, NY	0.52 0.29	Wang et al. (2016)
Israel	NA	NA	Olsson (2012)
Greece	Activated Sludge Wastewater Treatment Plants	0.12, and 2.19	Siatou et al. (2020)

the WWTPs are currently producing excess biogas for transmitting electricity back to the grid. Table 2 displays the national-level intensity of energy proportion and consumption in WWTPs for various nations.

Israel uses 10% of the energy in the world, which seems like a lot more than other nations. The severe water shortage issue in Israel may have played a role in this. The most popular technologies for the lagoon and trickling filters are used in South African WWTPs, where the electricity intensity ranges from 0.079 to 0.41 $kWh.m^{-3}$ (Wang et al. 2016). The energy intensity of India and Korea utilizes almost the same 0.24 $kWh.m^{-3}$. According to estimates, a municipality's total energy use for public utilities accounts for about one-fifth of the energy used in its WWTPs, and due to rising water consumption and stricter regulations, this percentage is expected to increase by 20% over the next 15 years. Therefore, it is essential to optimize the WWTP's energy utilization efficiency.

BIOFUELS AS A PROMISING ALTERNATIVE AND RENEWABLE ENERGY

Biofuels are fuels that have energy from living organisms that have recently fixed carbon in the earth's atmosphere. Starch, vegetable oils, animal fats, waste biomass, or algal biomasses—all of which are non-toxic, biodegradable, and renewable—can be used to make biofuels (Song 2008). Biofuels are divided into first, second, third, and fourth-generation biofuels based on the types of feedstocks used and their current and future availability (UNEP 2009). They benefit the environment because when used, harmful emissions like those of CO_2, hydrocarbons, and particulate matter are reduced, and Sox emissions are eliminated, which reduces the impact of greenhouse gases. In actuality, burning biofuels releases less carbon into the atmosphere than burning fossil fuels because the carbon released is already present in the current carbon cycle (Popp 2014).

The generation of biogas in WWTPs can be increased in several ways. The use of a process for anaerobic co-digestion (AcoD) is among the most promising. To increase the efficiency and stability of the anaerobic digestion (AD) process, a suitable, carefully chosen substance is added to the primary substrate. Several applications of the AD process have been reported thus far (Rabii 2019).

Microalgae: A Versatile Option for Sustainable Energy

Microalgae have long been regarded as a promising replacement for renewable feedstock in the manufacture of biofuels. This study evaluated the probable suitability of two different species, *Chlorella minutissima* along *Nannochloropsis gaditana*, to be assessed as essential components for ethyl esters that produce biodiesel value considering the presence of the numerous oleaginous strains of microalgae (Zorn 2022). Microalgae have received a lot of attention recently due to their potential as energy crops, the worth of the natural products they produce, and their capacity to clean up effluents. Algal fuel, also known as oilgae or third-generation biofuel, is a biofuel made from algae. This is the best course of action for the production

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of biofuels because algae have enormous possibilities for renewable energy functions (like a low-input, high-yield prospect) (Satyanarayana 2011). As a result, this potential may make it possible to completely replace transport fuels made from petroleum without resorting to the contentious “food for fuel” argument. Microalgal biofuels are receiving more attention these days as a result of growing issues over fossil fuels, availability of energy, greenhouse gas emissions, and the claim that other biofuels can be used as “food for fuel” (Pienkos 2009).

The global energy crisis and rising greenhouse gas emissions have sparked the need for new, renewable energy sources that are environmentally friendly. Microalgae biofuel has the potential to displace fossil-based fuels and is one of the primary forms of renewable energy for sustainable growth, according to life cycle analysis. The main drawbacks of oil crops and lignocellulose-based biofuels were not present in microalgae biofuel. Algae-based biofuels are technically, economically, and cost-competitively viable. They don’t need any new lands, use a lot less water, and reduce Iic CO_2. However, because of the low concentration of biomass and expensive downstream processes, the commercial manufacture of microalgae biodiesel is still not practical (Medipally 2015).

Designing sophisticated photobioreactors and creating low-cost methods for harvesting, drying, and oil extraction from biomass will enable the viability of microalgae-based biodiesel production. In order to control environmental stress conditions and engineer metabolic pathways for high lipid production, commercial production can also be achieved by enhancing genetic engineering techniques. Algal-bacterial interactions for enhancing microalgal growth and lipid production are among the new emerging technologies that are being investigated. This review primarily focuses on the issues that arise during the commercial generation of microalgae biofuels as well as potential solutions (Udayan 2022).

SOLAR-POWERED AND BIOGAS WASTEWATER TREATMENT TECHNOLOGIES: ADVANCEMENTS AND CHALLENGES FOR SUSTAINABLE DEVELOPMENT

Water treatment systems that are economical and sustainable are essential for developing countries. The availability of water is failing to keep up with the growth in the human population in India. Based on tested theory and technology, a flexible, affordable, and environmentally friendly wind/solar-powered wastewater treatment system is suggested. The proposed system is used to demonstrate how it functions in a household in India where wastewater is recycled utilizing an innovative combination of water purification devices driven by solar/wind energy. The system that is being used in this demonstration is specifically made for small-scale applications, such as for a single household.

Access to clean water is now the main concern for contemporary society. The process of treating wastewater that commercial and industrial operations have contaminated requires a lot of energy and relies on traditional energy sources. There is growing interest in solar energy as a potential solution for water treatment. Simpler systems like solar stills and SODIS and more sophisticated ones like MD, MSF, and RO can all be used to treat wastewater using solar power. The choice of these technologies depends greatly on the site. For tropical countries with plenty of solar energy but little investment or skilled labor, solar still and SODIS are suitable. Compared to solar MSF and solar MD, solar MED is more economically and technologically competitive. Although prohibitively costly, the PV-RO system is feasible. Modern market opportunities could result from these technologies being upgraded (Sansaniwal 2022).

All types of waste management demand a lot of energy, which is hard to come by during the global energy crisis. Both types of waste, i.e., solid and liquid, are actively treated using a lot of solar energy. According to Ugwuishiwu et al. (2016), methods including solar desalination, solar pathogenic organic destruction, solar photocatalytic degradation, along solar distillation are implemented to treat liquid waste. The challenges of cleaning up wastewater using solar energy are highlighted in the following section and are illustrated in Fig. 4 despite the advantages of each technique for water treatment (Pandey 2021).

Wastewater is regarded as an alternative way to generate energy (Frijns 2013). The biogas formed in the digester is the major source of energy in a WWTP. In comparison to a WWTP without sludge digestion, one with pre-settling and sludge digestion uses 40% less net energy on average. Some WWTPs, including Strass (Austria) (Schaubroeck 2015), Steinhof (Germany) (Remy CaL 2015), Sheboygan (America) (Sheboygan 2015), and others have adopted sludge anaerobic digestion with Combined Heat and Power (CHP). Sludge digestion is already widespread practice in the Netherlands, where many WWTPs produced 95 million Nm^3 of biogas in 2006, which was then converted to electricity (143 MWh) and heat (used to heat the digestion reactor) by a CHP mechanism (Frijns 2013). Several WWTPs integrate kitchen wastes with sludge for anaerobic co-processing to stabilize kitchen waste materials. This aids in substrate modification, improves organic loads, biogas yields, and the generation of energy, as well as increases equipment capacity factor, and lowers investment (Kai 2005). Although it still needs a lot of development before it can be used in practice,

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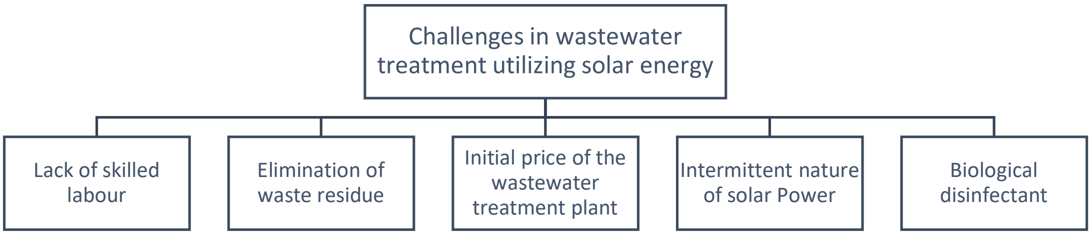

Fig. 4: Challenges in WWTPs using solar energy.

microbiological fuel cell (MFC) technology can generate electric power from wastewater (Li 2015).

A significant source of renewable energy is the thermal energy found in wastewater. Thermal energy generated from wastewater can be used to heat nearby homes or be transmitted to the district heating system by using heat exchangers and heating pumps. Using China as an example, it is entirely feasible to offset the energy deficit caused by insufficient energy conversion from excess sludge by recovering at least 50% of the energy consumed by a WWTP from thermal energy (Hao 2015). The amount of heat generated during treatment processes exceeds the amount of energy required for plant heating. Changing the heat source of heat pumps for district heating from wastewater to cooling water regeneration is another way to provide heat and save money at the same time.

Rising energy needs are a result of the quick increase in the human population, and by 2030, those needs are expected to rise by at least 50%. The current rate of consumption, which is reportedly 105 times faster than what nature can produce, cannot be met by natural petroleum (Maness 2009). Furthermore, the combustion of fossil fuels harms our environment by emitting greenhouse gases, which causes global warming. Thus, finding "clean" energy has become one of the most difficult tasks. Various alternatives are currently being researched and put into practice. Biofuels, or fuels derived from living organisms, are advantageous for the environment because they reduce harmful CO_2 and hydrocarbon emissions and eliminate SOx emissions, which reduces the greenhouse effects. Scenedesmus obliquus is highlighted as one of the micro-algal species that have so far been found to be suitable for the production of biofuel. The most recent initiatives and successes in enhancing production economies by genetic as well as metabolic engineering of microalgal strains are also covered. Other potential uses for biofuel production are described, including CO_2 mitigation and wastewater treatment. The biofuel industry's promises and obstacles related to algae are finally revealed (Shubha 2018). Rittmann (Medipally 2015) outlined three risks associated with relying on fossil fuels: diminishing fossil fuel reserves, the geopolitical conflict caused by resource scarcity, and climate change brought on by rising atmospheric CO_2 concentrations. As a result, finding "clean" energy has emerged as one of the most difficult problems.

CONCLUSION

The purpose of the current review work is to address specific queries that will aid in a better understanding of how solar power can be used to treat domestic and commercial wastewater. A detailed review is done on the main issues, such as the pollutants found in domestic and industrial wastewater, wastewater treatment methods, and the environmental advantages of treating wastewater. In this review paper, we discussed how much energy is currently used by WWTPs and browsed into the potential of developing energy-self-sufficient WWTPs. Recent attention has been focused on research initiatives on microalgae and their production on a global scale due to these desirable characteristics of microalgae. Even though current technology only makes up a very small portion of total energy consumption, solar thermal system research has been steadily progressing for decades.

It is expensive to remediate water using some treatment methods because they involve high energy input. The presence of pollutants in the wastewater, such as chemical pesticides, hydrocarbons, colorants (dyes), surfactants, as well as aromatic compounds, is causing additional problems. The hazardous substances cannot be eliminated by one method of treatment. The degradation of a variety of contaminants using innovative and alternative greener technology is, therefore, the focus of research. Utilizing solar energy for wastewater treatment reduces the need for conventional power, which lowers GHG emissions. Although pollution can be completely reduced by solar photocatalysis or solar thermal electrochemistry, the removal of waste sediment following wastewater treatment with solar desalination requires additional steps.

FUTURE PROSPECTS

Many scientists and government officials from various nations have given the issue a lot of thought. Researchers spend a lot of time studying microalgae, and many

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governments contribute a sizable sum of money to microalgae-related projects. Despite the numerous obstacles to the production of microalgal biodiesel, more and more innovators are persuaded that the benefits will eventually outweigh the risks, and, to date, microalgae investments have exceeded $900 million globally. To examine future development opportunities, it is necessary to discuss the research gaps, market opportunities, and future advancement directions of solar energy in wastewater plant systems. Even though the construction of energy-self-sufficient WWTPs is undoubtedly feasible, there are still numerous obstacles to overcome, especially in developing nations. Additional work is required in technological advances, expenditures, and safeguarding the environment.

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