DOI: https://doi.org/10.52756/ijerr.2022.v28.005 *Int. J. Exp. Res. Rev.*, Vol. 28: 30-37 (2022)

Review Article | Peer Reviewed | Open Access

International Journal of Experimental Research and Review (IJERR)

ISSN: 2455-4855 (Online)
www.iaph.in

A multidimensional study of wastewater treatment

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Article History:
Received: 15th May, 2022
Accepted: 14th Jun., 2022
Published: 30th Aug., 2022

Keywords:
Disinfection, septic tank, wastewater, water sus-tainability, water treatment.

Abstract: Water usage generates wastewater, which must be collected and treated properly before being returned into the hydrological cycle for reasons of sustainable development and water supply. The content and volume of waste water generated are determined by a range of elements, as most of them are the waste of households, industries and so on. It also dictates the necessary treatment methods. Waste water treatment facilities function at a crucial stage in the water cycle, assisting nature in protecting water from contamination. Treatment methods can be categorized into four segments: preliminary, primary, secondary and tertiary wastewater treatment. Screening and grit removal are ordinary parts of preliminary wastewater treatment. Basically, it prepares wastewater for further treatment. Although the primary purpose of wastewater treatment is to separate easily-removable suspended particles and BOD, wastewater components that occur as dissolved solids or settleable wastewater solids may also be eliminated here using a septic tank, the Imhoff tank. The conversion of organic materials to more oxidised or reduced forms occurs in treatment plants of secondary wastewater treatments and sometimes in tertiary treatment also. Disinfection and suspended particles removal are the most common techniques used to modify conventional wastewater treatment plant effluents for crop application. Advanced wastewater treatment, also known as tertiary treatment, is used in treatment technologies when a higher quality of water is desired but secondary treatment procedures cannot provide. Advanced or tertiary water treatment includes the removal of nitrogen, phosphorus, several organics and metals. Finally, the treated waters can be used for multiple purposes. Rainfall waters being less polluted, can be easily treated and fewer treatment methods will require here. However, to make them more efficient, several improvements are needed for commonly used systems like trickling filters, oxidising ponds, rotating bio contractors (RBCs), septic tanks, etc..

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Introduction

India has a vast water supply with 113 rivers and extensive alluvial basins to contain lots of groundwater. India is also fortunate with snow-capped Himalayan peaks that can supply the country's diverse water needs (Parua, 2010). However, due to the country's fast population growth and the need to fulfil rising irrigation, residential, and industrial consumption needs, limited water supplies in many regions of the country are depleting, and water quality is deteriorating (Biswas and Saha, 2021). Nowadays, the most severe environmental concern and hazard to public health in rural as well as urban India is a lack of suitable and safe drinking water as almost all the surface water is contaminated by either organic pollutants (including heavy metals like lead, arsenic, chromium, copper etc.) or by the common bacterial colony that cause serious illness to humans (Samal et al., 2017). Water treatment is undergoing a revolution and is becoming increasingly essential across the world as water becomes scarcer. It's very important to note that waste water is not just sewage water. Water is used in our home for various household activities, including toilets, bathrooms, showers, basins, dishwashers, washing machines etc., but when all those used, water is conveyed into sewers are, considered to be 'domestic wastewater'(Bury et al., 2002). From small business farms to large-scale industries, water is needed everywhere and they also contribute a large amount of wastewater which is termed 'industrial wastewater'. In order to conserve our natural resources and promote drinking water production, it's very necessary to purify the wastewater before being reintroduced to the water cycle.

Objectives

Main objective of this communication is to:
- Differentiate various types of water treatment process through a conventional sewage treatment plant.
- Understanding the primary goal of wastewater treatment in order to accelerate the natural purification processes.
- Recognizing how the treated water should be utilized in various aspects.

Methods and methodology

Collection of samples

Domestic wastewaters of municipal areas are collected by the sewers and delivered near the treatment plant. Industrial wastewaters being contaminated by organic pollutants are handled very safely, and most of them are brought to the treatment plant through long, underground pipes.

Steps involved in wastewater treatment

The majority of treatment facilities were designed to purify wastewater before it was discharged into streams or other receiving waterways or for reuse. Depending on the function and complexity of the process, wastewater treatment techniques may be divided into the following groups and a simple diagram is mentioned in Figure 2.

Preliminary Treatment

The goal of preliminary treatment is to get rid of the readily separable components. Screening is done to remove large objects, such as rags and sticks; therefore, grit removal is performed where cinders, sand, and small stones settle to the bottom. Their clearance is necessary to improve subsequent treatment operations' efficiency and avoid damage to pipes, pumps, and fittings (Morsy et al., 2020). Sewage still includes organic and inorganic materials and other suspended particles, notwithstanding its treatment. The most popular screening devices are bar screens, which have a standard spacing within bars of 15 to 25 mm. The rate of wastewater cleaning highly depends on the size of the apertures and screening production (David, 2016).

Primary Treatment

Primary treatment is simply the settlement of solid particles present in the wastewater. A particular amount reduces pollution load through this treatment. During primary treatment, below half of the incoming biochemical oxygen demand (BOD5), a high amount of the total suspended solids (SS), and some of the oil and grease are eliminated. In most cases of industrial wastewater treatment, primary treatment is considered sufficient if not consumed by humans. Septic tanks and Imhoff tanks are basic examples of primary treatment (Rebosura et al., 2021).

Secondary Treatment

After actively performing the primary treatment, sewage still contains organic and inorganic particles. In order to remove the residual organics and suspended particles from the effluent, secondary treatment is done. Several aerobic biological techniques are utilized for secondary treatment, with differences essentially in how oxygen is delivered to microbes and how quickly they metabolize organic material (Mittal, 2011). The treatment entails harnessing and speeding up the natural waste disposal process, in which microorganisms transform organic materials into stable forms through aerobic and anaerobic processes. The organic molecules' conversion is schematically represented in figure 1 (Mahdi et al., 2007).

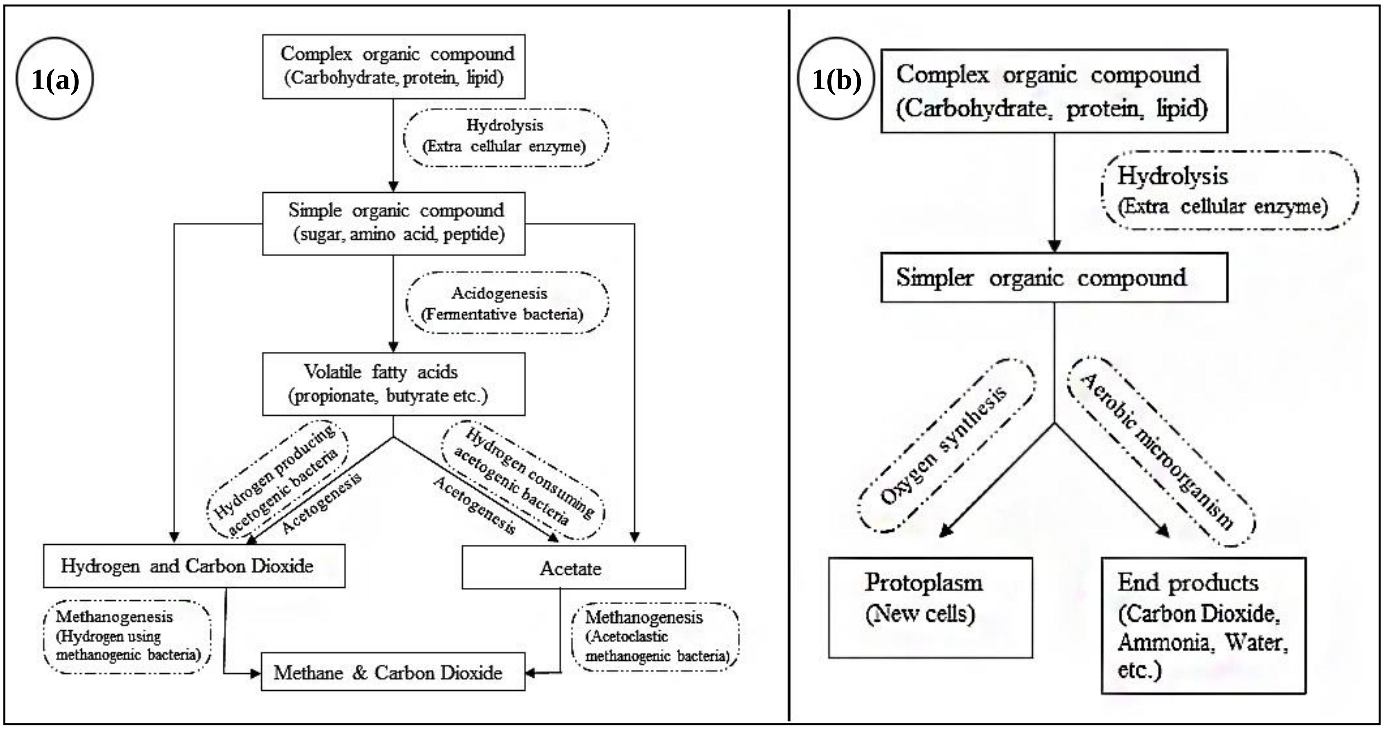

Figure 2. 1(a). Conversion of organic molecules by anaerobic treatment; Figure 1(b). Conversion of organic molecules by aerobic treatment.

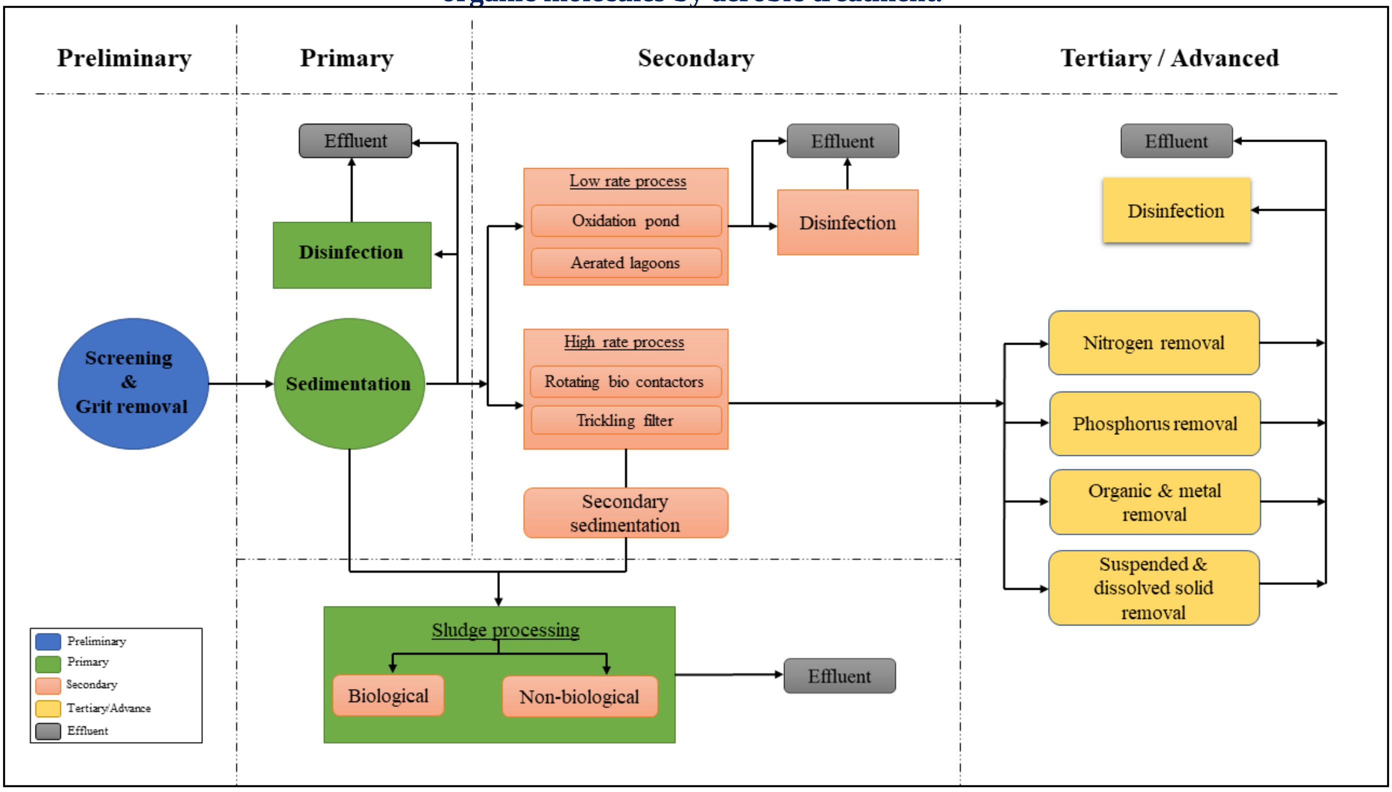

Figure 1. A simple diagram depicting the steps in the wastewater treatment process.

The strategy of biofiltration method is used here that employs sand, contact, or trickling filters. Another strategy is the activated sludge process, a time-consuming yet effective technique involving mixing wastewater with a microbial solution. To assure results, the final mixture is aerated for up to 30 hours at a time. In warmer climates, oxidation ponds are commonly employed using natural bodies of water such as lagoons. The fixed film reactors, also known as rotating biological contactors (RBCs), are slow spinning discs that treat wastewater by generating surface turbulence (Cortez et al., 2008).

Tertiary and/or advanced treatment

In case any specific type of constituents like nitrogen, phosphorus, additional suspended solids, refractory organics or specific industrial pollutants needs to be re

DOI: https://doi.org/10.52756/ijerr.2022.v28.005

Table 1. Commonly used wastewater treatment systems, the type of treating water and their advantage-disadvantage.

System Name	Type of Wastewater	Advantages	Disadvantages
Septic Tank	Domestic wastewater	Simple, long-lasting, and compact due to its subsurface location.	Low treatment efficiency, generates foul smell.
Imhofftank	Domestic wastewater	Durable, it has limited room and produces odourless effluent.	Very regular desludging is needed.
Anaerobic biofilter	Domestic wastewater narrow COD/BOD ratio	It is simple and fairly resilient if well-constructed and wastewater has been sufficiently pre-treated because it is underground. It has a high treatment efficiency and only takes up a small amount of permanent space.	Construction is costly due to the unique filter material used; filter blockage is probable; effluent smells somewhat despite high treatment effectiveness.
Baffled Septictank	Domestic wastewater of narrow COD/BOD ratio	Simple and long-lasting, high treatment effectiveness, less area, required due to subsurface location, less obstruction, and comparatively inexpensive compared to anaerobic filter	Poor wastewater, less efficiency, and a longer startup period than anaerobic filters.
Anaerobicpond	Domestic and strong and medium wastewater	Construction is simple, treatment options are diverse, and upkeep is minimal.	The wastewater pond is located on open terrain, there is usually some odour, which may be rather unpleasant, and mosquitoes are difficult to prevent.
Aerobicpond	Pre-treated domestic Wastewater	Construction is straightforward. Simple to build, dependable in performance when properly dimensioned, high pathogen removal rate, may be utilized to produce an almost natural environment. Fish farming is conceivable when large in size. Flexible in terms of treatment intensity and low maintenance.	If undersized, insects and stench can become a nuisance, and algae can boost effluent BOD levels.
Duckweed Pond	Sullage or Pre-treated sewage	Construction is simple, revenue is generated through pisciculture, and it is ideal for rural and semi-rural areas.	High space requirements and stink risk cannot be ruled out, and adequate duckweed harvesting is required.
Rotating Biological Contactor (RBC)	Domestic black- or greywater and any other low- or high-strength biodegradable wastewater	Short contact periods, low operating costs, short retention time, low sludge production and excellent process control are required.	In northern areas, RBC units must be covered to keep them from freezing and shaft bearings and mechanical drive components must be serviced often.
Trickling Filters	Mostly industrial wastewater contains organic matter.	Small land area is required, resistant to shock loading, simple, reliable and low power.	The skilled person needs regular maintenance, electricity and water flow are required, high risk of clogging is present.

moved from wastewater this tertiary treatment like bank's clarifiers, grass plots, etc. along with some advanced treatment methods are employed, which include hyperfiltration, carbon adsorption, reverse osmosis, electrodialysis like chemical treatment (Boeriu et al., 2013 ; Thakur et al., 2021).

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Disinfection is performed in almost all steps of the treatment process. The objective of disinfection is to keep harmful illnesses at bay. All organisms are not eliminated during the disinfection procedure. In contrast, sterilization entails the complete annihilation of all organisms. Bacteria, viruses, and other pathogens cause various water-borne illnesses (Madhav et al., 2020). Several chemical agents like chlorine, bromine, and ozone; physical agents like heat, and ultra-violate rays are accomplished in the disinfection process. However, gamma rays are sometimes emitted from radioisotopes that are also effective disinfectants (White, 1999).

Wastewater treatment system

From ancient times several techniques have been performed for treating wastewater without naming them. As civilization has progressed, so have those methods. The treatment systems we're using have many advantages but have several disadvantages too. Some of the commonly used systems are mentioned in Table 1 (Bashaar, 2004 ; Bury et al., 2002 ; David, 2016).

Uses of treated waters

The usage of treatable waters has an impact on the treatment process. However, it might be returned to the hydrological cycle in many ways. Reservoirs or ponds can be used to store the treated water (Kumar & Puri, 2012). We may utilize these treated fluids in situations where there is no direct human connection, such as residential process water used for toilets. We may also use them to wash automobiles, clean roadways, sidewalks, and pedestrian crossings, and green water vegetation in landscaping areas (Quach-Cu et al., 2018). Because agricultural water use is substantially larger than that of the civic sector and industry, recycled water in agriculture allows for significant water resource savings.

Notions which are widely used to treat wastewater

A single treatment technique is not enough for the treatment of wastewater. Various industrial wastes are incorporated with the sewage. In order to remove each and all the toxins, specific and elaborate procedures are to be executed. These may be categorized as below:

(a) Bio-electrical
(b) Microbes coupled with constructed wetland
(c) Electro-bio remediation
(d) Physiochemical
(e) Biotechnological
(f) Electro kinetic assisted phytoremediation
(g) Microbes-assisted phytoremediation
(h) Microbial desalination, cell and microbial electrolysis
(i) Anaerobic ammonium oxidation (anammox)
(j) Constructed wetland and microbial fuel cell

In the physiochemical process, the toxic water is treated with membrane filtration, ion exchange, advanced oxidation, and coagulation/ flocculation. These are advantageous because of their efficacy. At the same time, there are various toxins incorporated from industrial and agricultural wastes. This is why it becomes sensitive. Chemical consumption is excessive, and the operational cost is too high. The byproduct of all these courses of action is the generation of large amount of sludge (Kumar et al., 2022)

Many researchers contributed their research on wastewater remediation with the help of an indigenous group of bacteria consisting of RES19-BTP, *Cellulosimicrobium* sp., *Aeromonas* sp., AKD4-BF, BLA14-CF, *Xanthomonadalus* sp., *Sphingomonus* sp. and CST37-CF which degrades organic components of wastewater.
Waste water which contains Total Dissolved Solids (TDS) (2000 mg/L) is kept under severe restriction because it results in a loss in crop yielding due to a higher concentration of salt, as mentioned by the Food and Agriculture Organization (FAO).

Eucalyptus camaldulensis plant is highly effective in treating this wastewater. High amounts of various ions such as sodium, magnesium, calcium and potassium in waste water improve the production of biomass and chlorophyll of Eucalyptus camaldulensis and no negative result is found (Kumar et al., 2022). Among the raw organic materials, rice and coconut husk are combined with forest plant species, forming an excellent bedding material for managing high TDS.

Different bacteria and algae conjugal action can also degrade sewage. Bacterial enzymes decolourize and degrade azo dyes synthesized by industries by molecular docking. Algae remove the excess nutrients along with aluminium, nickel, and copper like heavy metals from wastewater. From their biomass, biofuels are produced, which is a potent byproduct of wastewater treatment (Kumar et al., 2022).

Bacteria consume organic matter and nutrients from wastewater. The oxidation and reduction remove the water's nutrients and provide oxygen to the algae. The algae consume inorganic nutrients and produce carbon dioxide, which is eventually taken up by the bacterium. This whole cascade intensifies the photosynthetic activity of algae (Kumar et al., 2022).

Nitrogen removal from sewage/ municipal wastewater is termed mainstream anammox. This is bringing a major shift in new-age wastewater treatment. National Environmental Pretection Agency of China held the limit of discharge 5mg NH4-N/L and 15mg TN/L for sewage. According to TaskGroup 2009, US, the value is 3 mg N/L. in Switzerland, the concentration of ammonium should be < 2mg NH4/L. In European Union the concentration limit is < 10 mg TN/L. for many years nitrogen removal technology from sewage was nitrification and denitrification. This bears high energy requirements, operational costs and emission of greenhouse gas. It brings the urge to develop more sustainable development of this procedure. The discovery of anammox bacteria (autotrophic anaerobic ammonium oxidation) changed the whole scenario. This bacteria was found in an anoxic zone of the sewage treatment plant. The removal of municipal waste is proven to be < 63% in consuming energy and < 90% in sludge production; carbon dioxide emission also shrinked to 90%. For anammox magnification bicarbonate, nitrite and ammonium are the key substrates. While nitrate is required to be produced for the treatment, ammonium is readily available in wastewater. The oppression of nitrogen oxidizing bacteria combined with unbalanced partial nitration gives rise to the very first conventional anammox (Rena et al., 2021). The orthodox anammox is operative at around 150C in order to achieve 70-90% nitrogen removal (Cho et al., 2019). Anammox bacteria are a chemo-lithoautotrophic and obligatory anaerobic member of the Planctomycetales order and comprise six genera. Despite the wide phylogenetic distance among the genera, they carry mutual cellular ultrastructure and metabolism. Hydroxylamine oxidoreductase (HAO) is the prime enzyme involved in the process. The bacteria are as follows: *Candidatus brocadia*, *Candidatus kuenenia*, *Candidatus jettenia*, *Candidatus scalindua*, *Candidatusanammoxoglobus* and *Candidatus anammoximicrobium* (Rena et al., 2021).

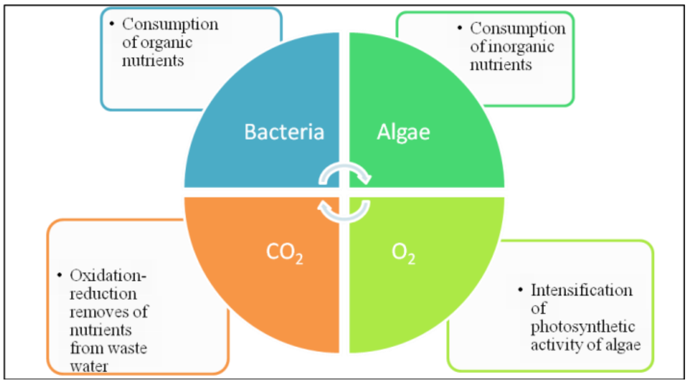

Figure 3. The symbiotic relation between bacteria and algae in water treatment.

Wastewater exhibits a high amount of coliform bacteria, parasitic eggs and cysts from the discharge of municipal wastes (Ghoreishi et al., 2016). Derayat et al. (2011), show that stabilising the pond ecosystems is a proven way to discard the parasitic eggs and cysts (Aghalari et al., 2020).

Discussion

Automation in sewage treatment is an emerging science that could be a proven way to create a sustainable environment. Various scientific investigations and analyses are in progress to improve the methods. Biochar has appeared to be a cleaner on account of its bottommost pyrolysis temperature and low production cost for activated carbon. It is also very desirable for the scientific community for its contribution to soil remediation. Organic solid wastes such as bamboo and, wheat straw, coconut husk can give rise to well-ordered biochar, which adsorbs organic contaminations and metals from water. To bypass the high financial cost and gain sustainable environmental recycling of sewage biochar is proven advantageous (Tang et al., 2019). Isotope labelling technology helps confirm anammox's contribution to nitrogen elimination with progressive organic polymer. Anammox is a proven bonafide exercise (Wang et al., 2019). Sugarcane bagasse (fibrous part of sugarcane after juice extraction) is treated with bleaching, alkaline hydrolysis and acid hydrolysis to derive nanocellulose particles which are identified by Fourier transform infrared spectroscopy (FTIR). This nanoparticle is used to decolouriseMalachite Green dye via the Batch procedure (Ghosh et al., 2020).

The orthodox method of treating wastewater could not remove the microplastics, which in turn enter the aquatic bodies if untreated. Membrane bioreactors reduce the number of microplastics up to 96.2%. Ozone is a strong oxidizing agent that treats microbes, inorganic ions and unwanted organic matter. Ozone is widely used to eliminate odour and taste. Pesticides can be eliminated using photocatalysis, including CuS, ZnS, WO_3, TiO_2, ZnO, and C_3N_4 (Shah et al., 2021). Considering different parameters and components of sewage and treatment procedures, an online surveillance system coupled with artificial intelligence could be developed to treat the wastewater, which is indeed a futuristic approach to creating a sustainable environment and research.

Conclusion and Future Scope of the study

In the future, treated wastewater will definitely be a vital alternative to fresh water. Rainwater collection and reuse can save up to half of the freshwater used for different household uses. Rainwater treatment is very essential and the path to future research on this topic is very promising. Several disadvantages and advantages of various types of wastewater treatment systems are mentioned here. It is important to improve the systems to make them ideal for wastewater treatment. Every government should build more treatment plants and run public awareness campaigns so that the general public understands the need for recycling. A moderate amount of wastewater has been collected regularly from the municipal area, but no such initiative is being taken in the village areas. Corresponding development authorities should implement the collection and transport of wastewater by various means.

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How to cite this article:
Aishwariya Das, Avik Kumar Saha, Shrubawati Sarkar, Soumok Sadhu, Taniya Sur, Shree Agarwal, Soumik Mazumder, Sheerin Bashar, Sambit Tarafdar and Sk Soyal Parvez (2022). A multidimensional study of wastewater treatment. *International Journal of Experimental Research and Review*. 28: 30-37.
DOI : https://doi.org/10.52756/ijerr.2022.v28.005