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Review - Environmental Sciences

Sustainable Waste Water Treatment: Opportunities and Challenges

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HIGHLIGHTS

- Wastewater treatment and monitoring strategies.
- Comparative analysis of wastewater treatment processes.
- Reuse of wastewater for alternate purposes: opportunities and challenges.

Abstract: Exponential increase in population has led to the release of large amounts of unregulated and untreated wastewater into water bodies such as rivers, lakes, streams, and estuaries causing various environmental and health issues. Traditionally various procedures are applied for the treatment of wastewater at the local and municipality level. Due to the increased need and development of newer technologies, it is necessary to understand all the available procedures and evaluate their efficiency. In the present review, all the important methods involved in the treatment of wastewater and its monitoring have been comprehensively discussed and compared along with their advantages and disadvantages. Information will not only help in understanding the treatment of wastewater but it will also help in developing procedures for the reuse of treated water for various alternative purposes.

Keywords: Wastewater, Primary treatment, Secondary treatment, Tertiary treatment, Reuse of treated wastewater

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INTRODUCTION

Most of the freshwater on earth is present in the form of snow and glaciers, and only 0.1 percent is present at the surface level in the form of rivers, lakes, streams, etc. majority of which is consumed by human beings [1]. It is estimated that there will be a three times increase in the consumption of water by the second half of the 21st century. The main use of water by humans is for biological survival [2]. A huge amount of water is also being used for agricultural and industrial purposes. Water pollution is another growing concern that affects the quality of water leading to the decreased availability of actually usable water [3].

Apart from drinking; water is used for several other purposes in daily life such as cooking, washing, flushing, bathing, toiletries, etc. which enters into the sewage collection system from urban and rural areas [4]. Although, most of the times industrial wastewater is treated separately but occasionally industrial wastewater gets mixed up with sewage [5].

The treatment of water is helpful in (i) preventing the spread of water borne infections due to the presence of harmful chemicals and pathogenic organisms (ii) minimizing environmental pollution (iii) reusing the treated water for various purposes [6]. Various strategies are applied for the treatment of sewage. Increased urbanization and industrialization have affected the quantity and composition of sewage which necessitates the standardization of various strategies and the development of new treatment methods [3]. For this, it is required to comprehensively review the various available techniques used in the treatment of sewage.

In the present review, characteristics of wastewater, its treatment and evaluation along with allowed standards have been discussed. Future perspectives of treated wastewater in terms of its reuse have also been summarized.

Characteristics of sewage water

It is important to characterize wastewater in terms of various parameters:

Physical Parameters

Temperature

The temperature of sewage affects the solubility of oxygen. The aerobic treatment of sewage is influenced by the rate of its biological activity and aeration equipment transfer capacity. In areas where the temperature is either very low or high, it adversely affects the activity of the biological treatment system and sedimentation efficiency [7].

pH

pH mainly affects the biological activity of various organisms which are involved during the treatment of sewage. The pH of the raw sewage varies depending on the source. Mixing of sewage with industrial wastewater can cause extreme fluctuation in pH [8]. By recording the initial pH, treatment procedures can be standardized to maintain the H^+ ion concentration.

Color and Odor

Depending on the concentration of contaminants, household wastewater has a slightly soapy and cloudy appearance. Over the time, sewage becomes old, darkened due to the activity of microorganisms and starts giving a pronounced odor [9].

Major polluting components of sewage water

Although 99% of sewage is water but the remaining 1% includes organic, inorganic and biological components, which can be in dissolved, suspended or volatile form. Their removal is must before the discharge of sewage into natural bodies and its application for other purposes [10,3]. For the effective removal and to make a decision for the disposal/use of treated water, it is important to know their relative concentrations. Major pollutants of wastewater are summarized in Table 1.

Table 1. Major pollutants in wastewater and their associated risks

Pollutant Name	Polluting Components	Effect of the Pollutant
	Organic components	
Organic matter	Fat, oil, solvents, detergents, pesticides, phenols	Toxic effect on aquatic life, bioaccumulation in the food chain
	Inorganic components	
Heavy metals	Hg, Pb, Cd, Cr, Ni	Bioaccumulation
Nutrients	Nitrogen, phosphorous	Eutrophication, oxygen depletion
Other inorganic materials	Acids, bases	Corrosion, toxic effect
	Biological components	
Microorganisms	Bacteria, fungi, viruses, protozoa	Spread of waterborne diseases

Organic components

Raw sewage contains many organic components like carbohydrates, fats, surfactants etc. Their presence causes depletion of dissolved oxygen which affects the aquatic life and posseses other environmental problems [11]. Some of these organic contaminants get bioaccumulated and cause many toxic effects.

Inorganic components

Major inorganic components in wastewater include heavy metals (such as mercury, lead, cadmium, chromium, nickel etc.) and nutrients (nitrogen and phosphorus) [12]. Inorganic pollutants are prominent where waste from industry such as tanneries, metal processing, fertilizers, mining etc. gets mixed. Apart from this it also leads to the addition of acids and bases. Most of the inorganic pollutants are non-biodegradable, have a tendency to bio-accumulate and pose substantial health risks even at extremely low concentrations [13]. Moreover they can cause problems such as corrosion and eutrophication.

Biological components

The sewage consists of human and animal excreta which are the carrier of many biological components such as bacteria, viruses, fungi, protozoa and parasites [14]. These components if not treated/removed properly at the risk for many waterborne diseases such as cholera, diarrhea, typhoid, amebiasis, hepatitis, gastroenteritis, giardiasis, etc.

Treatment of sewage wastewater

Sewage treatment is a process that includes physical, chemical and biological processes to remove an enormous number of pollutants before discharging effluent back into the environment. The treatment system is divided into four categories; pretreatment, primary, secondary and tertiary treatment [15]. Figure 1 depicts a diagrammatic representation of a sewage treatment plant.

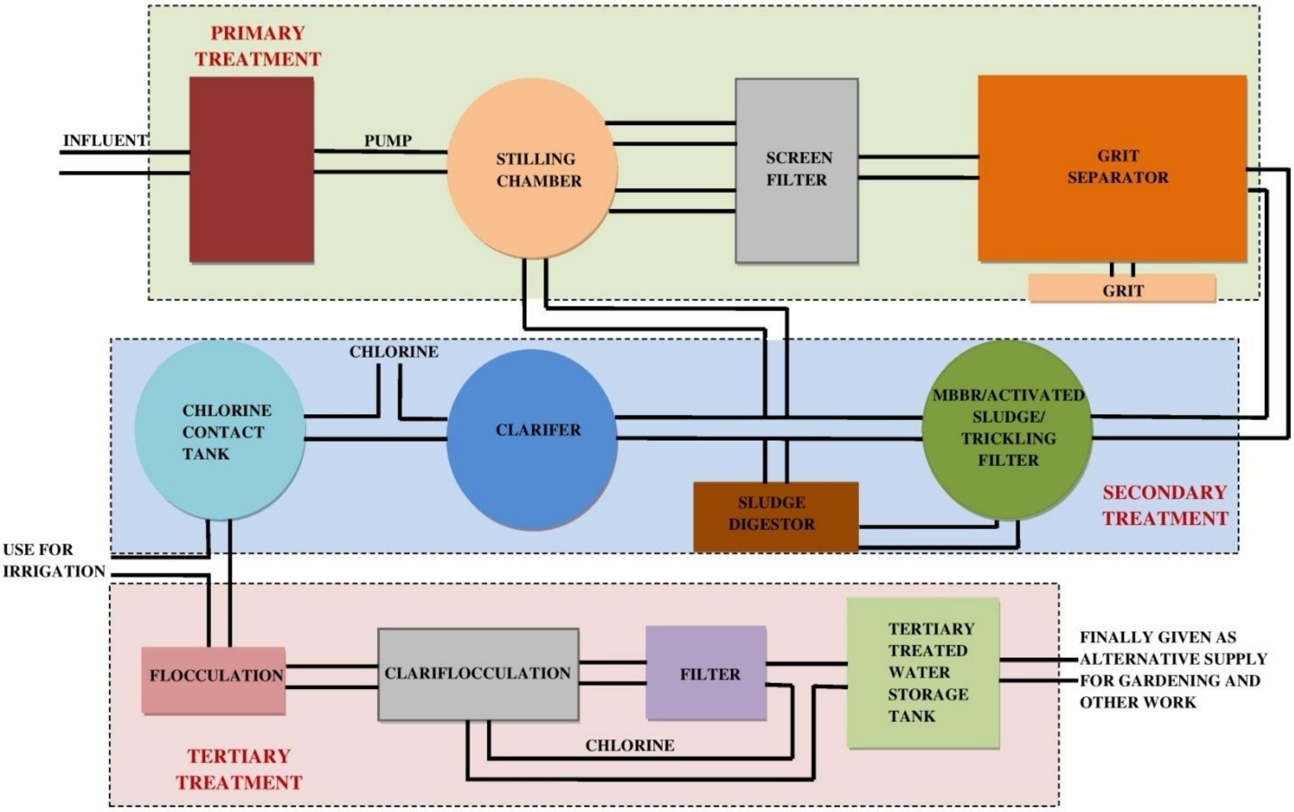

Figure 1. Layout plan of a sewage treatment plant

Collection system

A sewage collection system composes pipes and conduits which transport wastewater from its source to a treatment facility or disposal site [16]. Sewage becomes anaerobic if it spends too much time in the sewers, the collection system must be designed so that it reaches the treatment system as soon as possible after entering the sewers.

Pretreatment

Pretreatment is the process of removing large solids (those with a diameter greater than 2cm) and grit (heavy solids), oil, grease etc. by screening [17].

Bar screens

A grating of steel bars spaced about 2–4 cm apart is positioned at an angle to the flow of sewage through an open channel [18]. It helps in removing large solid particles such as plastics, cans, pebbles, etc.

Grit chamber

In grit chamber the flow velocity is reduced to the point where denser sand and other grit settle out but organic solids remain suspended [19]. The material that has settled is either buried or used as fill.

Primary settling tanks (or basins)

In the primary settling tank the water is made to stand which leads to the settling of the solids at the bottom, while oil and grease rise to the surface. It works by lowering the flow velocity to approximately 0.005 ms^{-1}, allowing the suspended material (organic settle able solids) to settle out [20]. Detention usually lasts between 2 to 3 hours. Longer periods of time usually result in dissolved oxygen depletion and anaerobic conditions. The solids are scraped off from the bottom, and scum is removed using high-pressure water jets. Suspended solid removal ranges from 50-65 percent leading to 30-40 percent in biochemical oxygen demand (BOD). The liquid from the primary settling tank is directed for secondary treatment, where aerobic decomposition completes the stabilization.

Secondary treatment (Biological sewage treatment processes)

The secondary treatment process uses aerobic and anaerobic microorganisms to degrade dissolved organic matter in the sewage [21].These microorganisms do the decomposition and release the carbon dioxide and other by-products. Based on the technology, secondary treatment methods can be described as traditional and modern methods.

Traditional sewage treatment methods

Most of the sewage treatment plants are based on traditional methods which use a combination of physical, chemical and/or biological processes that remove colloids, organic matter, nutrients and soluble contaminants [22].The different types of traditional methods are:

i. Activated Sludge system (AS)
ii. Trickling Filters (TF)
iii. Rotating Biological Contractors (RBC)
iv. Waste Stabilization Ponds (WSP)
v. Aerobic Lagoon (AL)
vi. Constructed Wetlands (CW)
vii. Fluidized Aerated Bed Reactor (FAB)

Activated sludge system (AS)

Activated sludge is a multi-chamber reactor that breaks down the organics present in wastewater using aerobic microorganisms and produces high-quality effluent [21]. A consistent and well timed supply of oxygen is required to maintain aerobic conditions and keep active biomass suspended. The microbes oxidize the organic carbon in the wastewater, resulting in the formation of new cells, carbon dioxide and water. Although aerobic microorganisms are the most common, some facultative anaerobes are also involved in the process.

During aeration and mixing, the bacteria form small clusters known as flocs. When the aeration process is complete, the mixture is transferred to a secondary clarifier, where the flocs settle and the effluent is directed for further treatment or discharge. A part of the sludge is then recycled back into the aeration tank, and the cycle begins again [23]. Figure 2.

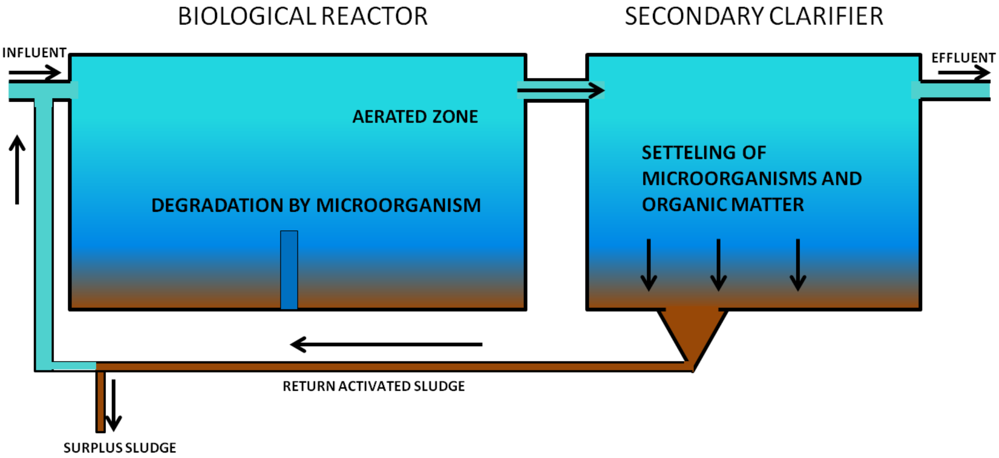

Figure 2. Activated sludge system

The proper operation of an activated sludge plant depends on the number of biological and physical factors that influence the efficiency of the process such as organic and hydraulic loading on the aeration tank, dissolved oxygen in the aeration tank, biosolids wasting rate, return activated sludge rate, clarifier loading, solids settling and compaction characteristics etc.

Trickling filters (TF)

A trickling filter is a type of biological filter that operates under aerobic conditions and has a fixed bed. The filter is sprayed with presettled effluent and 'trickled’. When water flows through the pores of the filter, the biomass that covers the filter material degrade organics [24].

Trickling filter is filled with a substance that has a high specific surface area, such as rocks, gravel, shredded bottles or preformed filter material. The pretreated wastewater is 'trickled' across the surface of the filter. Organisms that grow in a thin bio-film on the surface of the media convert the organic load in the wastewater to carbon dioxide and water while producing new biomass [25]. Figure 3.

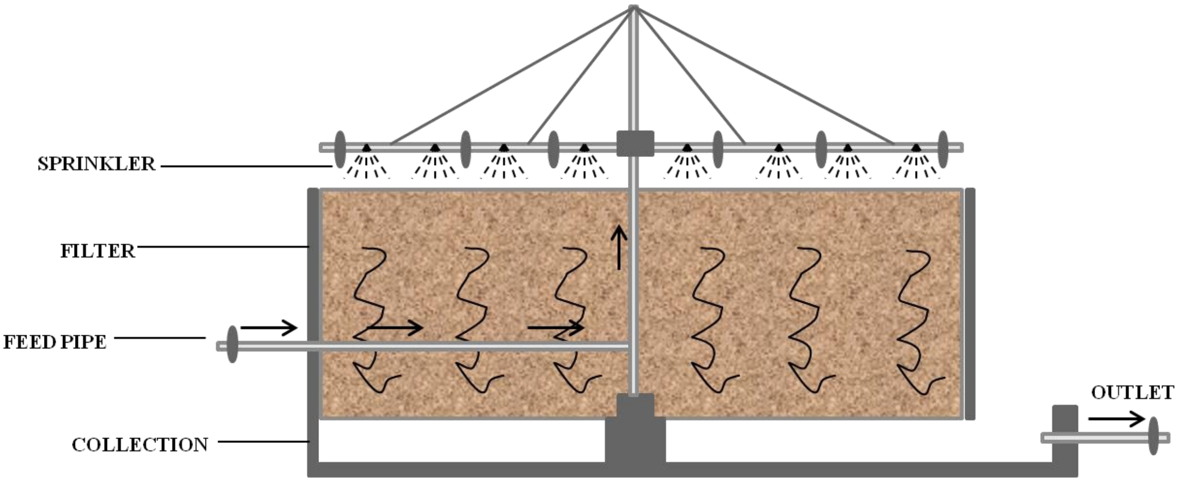

Figure 3. A diagrammatic view of the trickling filter

Rotating Biological Contractors (RBC)

Rotating biological contractors are also known as rotating biological filters, as they consist of a stack of rotating biofilm discs roped by a motor or air drive and positioned in a horizontal shaft. RBC includes a solid medium where microorganisms grow in a static biofilm [26]. The treatment combines the bacterial growth on RBC and biomass in the wastewater which oxidizes the nutrients by utilizing the oxygen in the air. It is able to completely remove nutrients such as ammonia, phosphorous etc. [26].

Waste Stabilization Ponds (WSP)

Waste stabilization ponds are the most common method used in the developing countries because of their low land cost and less expensive implantation [27]. In this process, the fecal sludge water is treated with the aid of natural conditions such as sunlight, wind, microorganisms and algae. Algal ponds are the most commonly used WSP where the sewage is treated by aerated photosynthetic oxygen produced by algae [28-29]. The only disadvantage of WSP is that the treatment procedure requires a protracted period of days to weeks. With the advancement of technology and software, the designs of WSP have been improved to reduce the treatment time.

Aerobic Lagoon (AL)

In the WSP, sometimes the growth of normal algae was retarded due to turbulence and other factors, which reduces the oxidation and thus lowers the quality of effluent. To overcome this, aerobic lagoons are used in which the sewage is aerated by a mechanical or subtle aerator to stabilize the oxygen within the sewage, prevent the settling of the suspended biomass and less time-consuming. The aerobic lagoon is divided into two types: aerobic and facultative lagoon [30]. In the aerobic lagoon, the power supply is sufficient to create the turbulence needed to keep the solid in suspension, whereas in facultative lagoon, the power supply is only sufficient to maintain the dissolved oxygen in the liquid.

Constructed Wetlands (CW)

Constructed wetlands are often used for the treatment of household, industrial and landfill leachate, for which advanced wastewater treatment is not economically viable. It is a convenient alternative to the activated sludge [31]. It makes use of natural processes involving wetlands, vegetations and microorganisms. It is economical as it does not require any chemicals, electricity or high treatment efficacy. However, it is a slow treatment process because anaerobic reactions are dominant [32].

Fluidized Aerated Bed Reactor (FAB)

The fluidized aerated bed reactor is an advanced hybrid biological system. In this, the wastewater is passed through a bed of particles at a sufficient velocity to cause fluidization in it. The particles are attached to the fluidized media and form a biofilm around the surface. It helps in the recirculation of wastewater [33].

Modern Sewage treatment method

Traditional processes are costly and require complex maintenance, to overcome these problems novel sustainable techniques have been developed and applied for wastewater treatment in public and industrial areas.

Moving Bed Bio Reactors (MBBR)

The most widely used approach is MBBR which is a combination of activated sludge and conventional fixed film systems. Its primary principle is the growth of biomass on plastic supports that move in the biological reactor due to agitation generated by aeration or mechanical systems [34]. Moving solid supports provides more surface area for microorganism growth as well as efficient aeration to treat wastewater. The MBBR process has many advantages which include a smaller reactor, faster reactions and no sludge-bulking problem [35].

Sequencing Batch Reactors (SBR)

The sequencing batch reactor (SBR) is a popular aerobic treatment technology for municipal wastewater as well as wastewater from industry such as refineries and petrochemical plants. A specific volume of wastewater, known as a “batch”, is screened first to remove larger particles from the water [36]. The SBR also serves as a clarifier, as the settle phase allows solids/biomass to settle without air flow or mechanical mixing. The main advantage of sequencing batch reactors is that they produce low levels of organic compounds in their effluent, allowing them to meet stringent effluent standards. It can be built on a small plot of land and is relatively easy to expand by adding more reactors [37].

Membrane Bio Reactors (MBR)

MBR combines traditional biological treatment with physical liquid-solid separation. Except for the sedimentation tank, it necessitates a smaller bioreactor. MBR technology generates high-quality effluent, higher volumetric loading rates, shorter hydraulic retention time (HRTs), longer solid retention time (SRTs), less sludge production and potential for simultaneous nitrification/denitrification in long SRTs [38]. However, the main disadvantage of MBR is fouling which reduces the membrane's efficiency and shortens its lifespan, necessitating extensive maintenance and cost [39].

Comparative analysis of commonly used secondary treatment methods

The secondary treatment is the most important step in wastewater treatment. It includes a variety of different processes for treatment [40]. For the effectiveness and improvement of wastewater treatment techniques, a deeper understanding of these processes is essential; therefore, a comparative analysis of secondary treatment is required to determine the most effective methods for removing pollutants in wastewater.

The two most commonly used methods activated sludge (AS) and moving bed bioreactor (MBBR) have been compared by several researchers (Table 2). In all the studies both techniques were found to be efficient with respect to the reduction of BOD, COD, TSS, AN etc. However, MBBR was found to be more efficient than AS to some extent.

Apart from the technique maintenance, monitoring and management of the treatment plant also play an important role in determining the efficiency of the treatment process. Most of the time monitoring by an in-house laboratory helps in increasing efficiency [41- 45].

Table 2. Comparative analysis of commonly used secondary treatment methods

Parameters (% Removal)	**Study 1[41]**		**Study 2 [43]**		**Study 3 [44]**		**Study 4 [45]**	
	AS	MBBR	AS	MBBR	AS	MBBR	AS	MBBR
BOD	84.28	94.28	68	65	--	-	-	-
COD	83.42	90.90	53	85	91.23	95.01	84	76
TSS	89.97	90.88	69	88	90.58	99.48		
AN	-	-	53	75			98	92
TN	66.6	91.66	-	-	61.04	65.86	-	-
TP	-	-	-	-	84.61	74.35	-	-
Oil and Grease	75	87.5	-	-	-	-	-	-

Legends: AS: Activated sludge; MBBR: Moving Bed Biological Reactor; MBR Membrane Bio Reactors; BOD: Biological Oxygen Demand; COD: Chemical Oxygen Demand; TSS: Total Suspended Solid; AN: Ammonia Nitrogen; TN: Total Nitrogen; TP: Total Phosphorus

Chlorination

After the secondary treatment, the treated water is collected in the secondary settling tank. It separates the sludge, removes the suspended materials and produces a clarified effluent. The most important process done at this step is the chlorination. Chlorination is done as per state and local regulations [40]. Chlorination helps in reducing the microbial load to acceptable limits. Often the load of microorganisms in the effluent is measured in terms of reduction in the number of coliforms, sometimes effluent is also evaluated for the presence of pathogenic microorganisms. Most of the time, the chlorine contact chamber dumps the treated sewage into water body.

Tertiary treatment

Due to stringent regulations and the increased reuse of treated water for various purposes other than agricultural use, it becomes necessary to further process the secondary treated water to make it suitable for such applications. Generally, the treatment is given to further reduce the particulates, organic contents, and microorganisms. This treatment may employ standard techniques with a longer detention time to allow more removals. Commonly tertiary treatment focuses on absorptive processes such as use of activated carbon, more efficient oxidation, foam separation of pollutants and demineralization through reverse osmosis or distillation. It may also employ more exotic and costly equipment’s such as electro dialysis units or ion exchange columns [46].

Ion exchange

Ion exchange is a process in which ions are removed from an aqueous solution and replaced with another ionic species. Ion exchange is based on the idea that a weakly bound ion can be displaced by a stronger bound ion. For demineralization, ion exchange is used in wastewater treatment to swap one ion with another. This process is most commonly used in domestic water softening [47].

Reverse Osmosis (RO)

Reverse Osmosis (RO) is a popular membrane filtering process that removes different types of molecules and ions from effluents by applying pressure to the effluents when they are passed through a selective membrane [48].The imposed pressure exceeds natural osmotic pressure by several orders of magnitude. The membrane used in reverse osmosis is typically 100m thick and made of cellulose acetate [49].

Ultrafiltration (UF)

Ultrafiltration is the most cost-effective advanced tertiary treatment for improving water quality. It is a membrane operation for clarification and disinfection. UF membranes are porous, all forms of microorganisms such as viruses and bacteria, as well as all types of particles, can be removed [50].

Comparative analysis of commonly used tertiary treatment methods

Although not much literature is available on the comparative analysis of various tertiary treatment methods but some studies have compared the most commonly used methods such as ultrafiltration (UF) and reverse osmosis (RO). Petrinic and coauthor (2015) and Jadho and Dawande (2012) have compared the treatment of hospital and industrial wastewater by these techniques (Table 3). In both studies, these techniques have been shown to treat the water effectively. However, RO was found to be a little more efficient than UF.

Table 3. Comparative analysis of commonly used tertiary treatment methods

	Study 1 [51]		Study 2 [52]	
Parameter (% Removal)	**Ultrafiltration**	**Reverse Osmosis**	**Ultrafiltration**	**Reverse Osmosis**
COD	22	100	97.6	99
BOD	10.13	100	98.5	99.9
TN	-	-	85	90
NH_4	20	100	95	98
NO_3	-	-	95	96
TP	42.5	91.30	66	70
PO_4	-	-	87	90
TSS	89.97	100	99.8	100
TDS	-	-	99.7	100

Legends: COD: Chemical Oxygen Demand; BOD: Biological Oxygen Demand; TN: Total Nitrogen; TP: Total Phosphorus; TSS: Total Suspended Solid; TDS: Total Dissolved Solid; NH_4: Ammonia; NO_3: Nitrate; PO_4: phosphate

Sludge digesters

The sludge which is formed during primary and secondary treatment is pumped into the sludge digesters, which are kept at a temperature of 30–35°C [53]. This temperature is ideal for anaerobic microorganisms. The average digestion time is 20–30 days but it can take much longer during winter. Only well-digested sludge should be withdrawn, with enough ripe sludge remaining in the digester to acclimate the incoming raw sludge [40]. The sludge that is generated after the treatment can be used as fertilizers, replanting landfill sites, road constructions, biofuel production etc.

Monitoring the efficiency of sewage treatment

It is very important to measure the efficiency of any sewage treatment system. The amount of organic matter in the effluent coming from the treatment system is a measure of the quality of the effluent, which is measured in terms of biological oxygen demand (BOD) and chemical oxygen demand (COD). Apart from this other parameters such as total solids, colors etc. are also measured in the effluent.

Biochemical Oxygen Demand (BOD)

BOD is the amount of oxygen required for the aerobic biochemical decomposition of biodegradable organic matter [54]. It is an iodometric titration procedure in which the amount of dissolved oxygen (DO) in the sample is indirectly determined in terms of iodine. It is the most common way to measure the amount of organic pollution in both wastewater and surface water. BOD of the treated effluent should be measured daily, sometimes to measure the efficiency of various steps BOD of the samples is measured at different stages of the treatment [54].

Chemical Oxygen Demand (COD)

COD is a crucial water quality indicator like BOD, it provides an index for determining the impact of discharged wastewater on the receiving ecosystem. COD represents the amount of oxygen required for the chemical oxidation of organic and inorganic matter. This test is based on the fact that a strong oxidizing agent, under acidic conditions, can fully oxidize almost any organic compound to carbon dioxide [55]. Higher COD values mean that there is more organic material that can be oxidized in the sample, which lowers the amount of dissolved oxygen (DO). COD is generally related to BOD as it is approximately 3 times the BOD. COD is preferred sometimes as it can be done in a short time of 2-3 hours whereas BOD takes 5 days. However, BOD represents more natural conditions than COD [56].

Other parameters

Apart from BOD and COD, other parameters such as total suspended solids (TSS), total dissolved solids (TDS), mixed liquor suspended solids (MLSS) tests and color, nutrients concentration, coliforms, etc. are done weekly to check the quality of sewage.

Effluent Standards

Effluent standards are regulatory standards for the concentration of pollutants in the treated water that is discharged into surface water from the sewage treatment plant. Different countries set their own standards for various characteristics of treated water (Table 4). Based on these standards, the quality of the water is evaluated; sometimes the treated water is further processed if it has to be reused for purposes such as recreation, irrigation, industry etc. [57- 65].

Table 4. Effluent Water Quality Standards of different countries

Parameter	pH	TSS (mgL^{-1})	COD (mgL^{-1})	BOD (mgL^{-1})	Nitrate (mgL^{-1})	Phosphate (mgL^{-1})	Coliforms (CFUml^{100})	Reference
Countries								
US EPA	6.0-9.0	<30	-	10	-	-	<200FC	[57]
WHO	4-8.6	40	100	40	30	25	<100TC	[58]
India	5.5-9.0	20	50	10	10	10	<230FC	[59]
China	5.5-8.5	60		40	-	-	<100FC	[60]
European Union	6.5-8.4	-	125	25	-	15	<100	[61]
Jordan	6-9	<15	100	30	30	30	100 *E.coli*	[62]
France	6-8.5	<25		35	-	-	-	[63]
UAE	6-9	-	50	5	50	30	-	[64]
Israel	6.5-8.5	-	<100	<10	<25	<5	<10FC	[65]

Legends: TSS: Total Suspended Solid; COD: Chemical Oxygen Demand; BOD: Biological Oxygen Demand; FC: Fecal Coliform TC: Total Coliform; E.coli: *Escherichia coli*

Reuse of wastewater for alternate purposes

Although the majority of the treated wastewater is mixed with natural bodies, to meet the increased demand, the reuse of treated wastewater has been suggested for several alternate purposes. However, the potential of wastewater reuse is determined by the quality of the wastewater, most of the times other treatments are given before its application for these uses such as additional chlorination, treatment with activated carbon etc. [46].

The most common reuse of treated water is for irrigation, aquaculture, fire suppression, construction, industrial cooling, maintenance of recreational reservoirs and domestic uses like car washing, toilets, etc. Figure 4.

Figure 4. Opportunities and challenges in the reuse of wastewater

Irrigation

Apart from agriculture reclaimed water can be used for irrigation of public parks, golf courses, urban green belts, cemeteries and residential lawns. Many developing and developed countries like China, Pakistan, Colombia, Syria, South Africa, Italy, Israel, US, Mexico, and Chile have successfully implanted the use of reclaimed wastewater for such purposes and the trend is being followed in other countries as well. It not only helps in saving water but also helps in reducing the use of fertilizers because of the availability of nutrients in the wastewater [66].

Industrial Reuse

After irrigation, application for industrial purposes is the second most important reuse of wastewater. Many industrial applications that do not require high-quality water such as cooling, boiler feed water, etc. can use treated water [67].

Direct Potable Reuse (DPR)

DPR is the processing of the treated wastewater to a level so that it can be mixed into municipal water supply systems and is used for drinking purposes. Although the first DPR scheme was set up in Windhoek (Namibia) in 1968, there have been fewer DPR projects set up since then due to public safety concerns. This is because the DPR may include pathogens and contaminants that pose a significant risk for diseases. However, it is still an alternative for areas where is a high scarcity of water [68].

Indirect Potable Reuse (IPR)

IPR is the discharging of treated wastewater into the ground for recharging the underground water level. In comparison to DPR, IPR is favored by the public because it can remove or inactivate pathogens and also improve water quality by allowing toxins to diffuse through the soil. Groundwater recharge and direct injection projects in Orange County, California, Fairfax, Virginia, and Singapore are examples of IPR initiatives [69].

Non potable domestic use

Treated wastewater can also be used for non-potable domestic purposes such as cleaning, toilets, car washing, etc. It helps in saving a huge amount of fresh water.

Other uses

Apart from these, treated wastewater can be used for aquaculture, construction and maintenance of recreational water reservoirs such as lakes, ponds, etc. [70].

Challenges in wastewater recycling and reuse

Despite the long history and emerging need for the reuse of treated water, several concerns are important which need to be looked into before allowing any such application. Any negligence in it can put the health of the public at great risk. Moreover, it can also affect the growth of plants and aquatic life thus, disturbing the whole ecosystem (Figure 4). Other considerations besides reuse water quality include socio-economic factors and hydro-geological conditions. Some of the most common concerns are:

Presence of microorganisms

The most important aspect to be taken care of while planning any strategy for the reuse of treated sewage water is the detailed qualitative and quantitative analysis of the microorganisms present in it. As large numbers of pathogenic organisms get discharged from the human body in feces, sewage water becomes a potential source for causing many diseases [66]. Sometimes it can lead to the endemic spread of waterborne diseases. Although measures such as chlorination are taken while treating the sewage but often it needs stringent monitoring. Microorganisms present in the wastewater can also seep in the soil with subsequent contamination of ground water [66].

Presence of heavy metals

Heavy metals are discharged into water when industrial waste gets mixed up with the wastewater. Because of their high solubility in water, heavy metals are easily absorbed by living organisms [68]. Heavy metals that enter the food chain may cause excessive accumulation in the human body and cause serious health problems [71].

Effect on aquatic life

In some studies, it has been shown that the dangerous compounds in treated water are bad for aquatic ecosystems. The presence of some of the compounds may directly affect the aquatic life or they can affect indirectly by the formation of algal blooms and habitat destruction [71].

Societal challenge

The biggest challenge to the reuse of wastewater is societal acceptance, because of the lack of awareness towards reclaimed water. Although the public has supported the reuse of water for industrial purposes, however in case of direct contact with the water such as during irrigation, most of the time the public does not support it. To increase the acceptability awareness program must be launched for the public at large [66,72].

Future prospective

With large quantities of wastewater to be treated and increased industrialization, several challenges are present that need to be addressed.

Developing energy-efficient procedures

The wastewater treatment process requires a large amount of electrical energy for its generation, which increases the cost of the treatment. It also results in the emission of greenhouse gases. To minimize the requirement for electrical energy and the generation of efficient energy in the form of biogas, newer processes need to be developed.

Industrial pollution

Mixing of industrial waste and sewage makes the treatment difficult and decrease the efficiency of the processes. Therefore, either they should be treated separately or industrial waste should be checked properly or pretreated before being discharged into the sewerage system.

Antibiotic resistance through wastewater

Anthropogenic activities have introduced antibiotic-resistance genes (ARG) and antibiotic-resistant bacteria (ARB) into the wastewater, resulting in the development of antibiotic resistant microbial pathogens, it has become a worldwide concern to the environment and human health. To minimize the spread of ARG and ARB, newer technologies must be developed, which are able to reduce the spread of antibiotic-resistant microbes and remove antibiotics.

CONCLUSION

With rapid urbanization and industrialization, wastewater generation has increased frequently. Therefore, the treatment of wastewater became an important factor before discharging it into the environment. Moreover, over the past few years, efficient treatment of wastewater has received special attention as the reuse of treated wastewater has been employed for several purposes. The comprehensive information in the present review with respect to wastewater characteristics, various available treatment procedures, and future prospects will help in increasing the efficiency of wastewater treatment and monitoring of wastewater treatment plants. Moreover, it will be useful to researchers to find out newer efficient ways of wastewater treatment.

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