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Biological Treatment Technologies of Pharmaceuticals from hospital wastewater

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Abstract

The increase of the human population increases the usage of pharmaceuticals for treatment and prevention of diseases in this world. The wide usage of pharmaceuticals, leads to the apt for environmental problems and create severe risks to water resources globally and also creates a serious threat to the aquatic environment. Hospital wastewater is the main source of the pharmaceutical wastes that causes negative impacts on human's life.The pharmaceutical wastewater consists of antibiotics, hormones, chemotherapy products, anaesthesia products and others. Disease causing pathogens can enter the wastewater from patients which can increase the risk of cancers among the people who could directly or indirectly exposed to such wastewater. When such untreated wastewater is discharged into the surface water it can create significant health risks to people. Mostly pharmaceuticals effluent contains a high level of pollutants and a complex mixture of active pharmaceutical ingredients, painkillers and microorganisms results in fatal effects on fish. Physical, chemical and biological characteristics of pharmaceutical wastewater are p^H, Colour, Alkalinity, CODand BOD. Microorganisms play a vital role for the removal of nitrates and phosphates.The biological treatments are activated sludge process, sequential batch reactor, extended aeration, membrane bioreactor, fluidized bed reactor, rotator biological reactor and others. In this paper the characterization and comparison of biological treatment methods of pharmaceutical wastewater is discussed along with their advantages and disadvantages which will help in the selection of suitable treatment method for the best performance.

Keywords:

Pharmaceuticaleffluent water;
Effluent characterization;
Biological treatment;
Microorganisms.

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1. Introduction

The pharmaceuticals are used in medical practices to treat the diseases in hospitals which has been increased from few decades [1]. A wide range of human medicines, including antibiotics, cytotoxins used in cancer treatment, are produced and used, some in the range of thousands of tons per year. Thus hospitals are widely considered as large contributors to the pollution of pharmaceuticals due to their discharge in wastewater. This wastewater contains compounds of toxic substances, antibiotics, steroids, hormones and chemotherapy products and other chemicals [2]. These compounds destroy the growth of the microorganisms. The presence of the antibiotics in nature can disturb the ecological balance and making the treatments difficult [3]. Pharmaceuticals are complex compounds with chemical structure mostly characterized by their ionic nature. Hospital originated wastewater is discharged to city sewage systems in many countries, treated together with domestic wastewater, and discharged to the environment without a specific pre-treatment[2]. The mixing of the wastes decreases the biodegradation process of the organic contaminant of WWTP as the concentration of pharmaceutical wastewater is higher than the concentration of the municipal wastewater [4]. Studies on antibiotics have shown that up to 95% of antibiotic compounds with higher concentrations of antibiotics can lead to change in microbial community structure and ultimately affect food chains [5]. Ecological studies report chronic long-term negative impacts of environment, human population and aquatic organisms to the pharmaceutical exposure. To eliminate the risks, it is necessary to remove the pollutants from the wastewater [6]. Characterization of wastewater is important to evaluate the treatment and quality of wastewater [7]. The characterization is to be done to determine the physical, chemical and biological characteristics and also to decide about the pollutant concentrations which has to be removed [8]. Different physico-chemical treatments such as sedimentation, coagulation, flocculation, sedimentation, sand filtration followed by activated carbon adsorption have been used to remove the pharmaceuticals from wastewater during the WWTP [9]. The wastewater quality parameters include pH, temperature, turbidity, conductivity, total hardness and total suspended solids (TSS) and very important biological oxygen demand (BOD), chemical oxygen demand (COD) and nutrients which are measured in terms of nitrogen and phosphorus should be characterized [5]. Biological treatment has been widely applied traditionally in pharmaceutical wastewater treatment plants due to its high efficiency and low cost. The biological methods are carried mainly in anaerobic and aerobic treatment processes by using various microorganisms. The dissolved organic matter can be removed easily in biological treatment which is a mixture of various dissolved organic carbon (DOC) and nitrogen (DON). It is very important to understand the relation between the microbial structure and the system stability of the wastewater for the removal of the pollutant and to maintain the treatment performance. Both aerobic and anaerobic treatment systems are feasible to treat wastewater from all types of effluents [10].This review paper gives a detailed study about the various biological treatments with their advantages and disadvantages.

2. Characterization of the wastewater

The physico-chemical parameters of wastewater as per Federal Environmental Protection Agency (FEPA), United States Environmental Protection Agency (USEPA), and World Health Organisation (WHO) are given in the following table. These are permissible limits for effluents discharged into surface waters.

Physico-chemical parameter	**FEPA**	**USEPA**	**WHO**
pH	6.0-9.0	6.5-8.5	6-9.5
BOD	50	ND	ND
TDS	2000	500	<1200
Chloride	600	250	250
Nitrates	20	10	50
Nickel	<1	0.005	0.002
Lead	<1	0.003	0.001

*All values are represented in mg/l and pH have no unit; TDS-Total Dissolved solids; BOD-Biochemical Oxygen demand; COD-Chemical oxygen demand; ND-not declared.

As per the standards given in the table, the wastewater beyond these limits should not be discharged into the water bodies without treatment. The high level concentrations in the wastewater causes environmental problems which will affect the plant, animal and human life [11]. Besides the physical and chemical characterization, the hospital wastewater also contains the biological characteristics of various potential hazardous materials including pathogens, disinfectants, drugs, chemical compounds and pharmaceuticals [12]. Therefore a suitable treatment technology and a proper treatment is required. The various biological treatments developed so far for the treatment are: Activated sludge process, Sequential batch reactor, Membrane bioreactor and others.

3. Biological Treatment technologies

3.1 Membrane bioreactor

The membrane bioreactor has been recently implemented in the treatment processes of the hospital wastewater [5]. It is the new technology which is intended for the water reuse from the effluent. It combines with the conventional activated sludge method by using the membrane filtration. The installed membrane in the bioreactor can separates the suspended solids and the effluent water. Generally the space requirement is small. The sludge concentrations in the aeration tanks is two to three times more than the conventional systems which states the effluent quality clearly and easily removes the micro pollutants from the wastewater. The membrane is a porous media which separates the particles and molecules in the wastewater. The principle involved is the membrane allows the passage of water through it and catches the suspended solids. The membranes are in the form of sheets, tubes and hollow fibres. The membrane process carried both in aerobic treatment and anaerobic treatment. In the aerobic treatment there is a 98% removal of suspended solids and 96% of COD and phosphorus removal is varies from 12%-74% [12]. In the anaerobic treatment due to the absence of aeration there is a low sludge production, lower energy consumption and production of biogas. The membrane process contains microorganisms which removes the pharmaceutical compounds efficiently. The removal of ibuprofen, carbamazepine, diclofenac, and metoprolol is high efficiency when compared with conventional system. Researches announced that treatment by MBR generated a better removals compared to activated sludge treatment for poorly biodegradable pollutants [5].There already exists various wastewater treatment technologies such as microfiltration, ultra filtration, nano-filtration, granular activated carbon, powdered activated carbon, reverse osmosis, electro dialysis reversal, membrane bioreactors, and others. But MBR have gained popularity in STPs and considered as a powerful tool.

S.No	Advantages	Disadvantages
1.	Produces high quality effluent	High cost
2.	Operated at high mixed liquor suspended solids concentration	Control membrane fouling
3.	High volumetric loading and shorter HRT	High energy costs
4.	Longer SRT	High cost of periodic membrane replacement

3.2 Activated sludge process

This is the common conventional treatment method to treat the hospital wastewater. The main principle of activated sludge process is that the microorganisms to feed on the organic contaminants in wastewater and grow in number and formed as particles; those particles are allowed to settle down in the tank which gives a clear liquid free of organic compounds and suspended particles. This process consists of a primary settling tank, an intermediate retention trough, two storage tanks and an aerobic tank [9]. This treatment process was originally designed for the removal of the suspended particles and COD. Due to the eutrophication problems, the treatment process involves the removal of nutrients like nitrogen and phosphorus [13]. Aerobic and anaerobic conditions are carried in the activated sludge process for the nitrification and denitrification processes [14]. The researchers briefly mentioned that during primary treatment process, the targeted compounds were not removed efficiently. But the using of activated sludge process caused a reduction of compounds detected between 30%-70% [13]. The higher degradation of the pharmaceutical wastewater was observed in the ASP but after the biological treatment the effluent has higher concentration because of the higher concentration of the influent wastewater [14]. The temperature, P^H, DO, HRT, organic loading, and toxic substances greatly affect the efficiency of treatment process. Mainly temperature plays a key role in which the selection of microbial diversity depends [15]. If the COD is 4000mg/l then activated sludge process is not suitable for the treatment. Therefore conventional activated sludge with a long HRT has been the best method for the treatment of pharmaceutical wastewater [16]. In the pharmaceutical wastewater treatment, diclofenac is the only uncovered compound during conventional treatment. The removal efficiency of the ibuprofen and naproxen are commonly higher than 75% and 50% respectively [13].

S.No	Advantages	Disadvantages
1.	Lower capital cost	High energy consumption
2.	Limited operational requirement	Production of large amounts of sludge
3.	Biological phosphorus removal	Operational problems like foaming and bulking
4.	Self-sustaining system	Temperature changes affects the tank

3.3 Sequential Batch Reactor

A Sequential Batch Reactor (SBR) technology is a periodic discontinuous process considered for the treatment of specific organic pollutants. It is a reactor in which an activated sludge process is carried out in a time-oriented, sequential manner using a single vessel for all the phases of the process [10]. The wastewater flows from one tank to another tank continuously over a periodic strategy. Hence it is known as time-oriented and batch process system. The steps such as aeration, pollutant oxidation, sludge settling, recycling involved in this reactor. It is also known as a draw-and-fill activated sludge process [12]. In SBR treatment process, each cycle starts with a empty reactor except for a layer of accumulated sludge on the bottom. Then the reactor is filled up with the treated wastewater and the aeration and agitation are to be started. The biological degradation process begins during the filling step and proceeds, until a satisfactory level of degradation of the pollutant is achieved. Then the aeration and agitation are stopped, and the sludge begins to settle. Depending on the time allowed for the sedimentation, anaerobic reaction can occur, which may reduce the organic content of the sludge. Once the sludge has settled, the clear top layer of treated wastewater is discharged and a new cycle can begin. The removal efficiency of SBR is 95-97% which produced effluent of quality having BOD_5< 5 mg/l, COD < 50 mg/l, TSS < 10 mg/l, Total nitrogen as N < 10 mg/l, Total phosphorus < 10 mg/l, E-coli removal is 99% MPN/100ml. SBR was found to be more effective in treatment of hospital wastewater [10]. The SBR can be operated either as labour – intensive, low-energy, high sludge yield can also be traded off with initial capital costs because of the flexibility associated with working in time rather that is space. The operational flexibility also allows designers to use SBR to meet many different treated objectives including time of construction, BOD and suspended solids reduction and nitrification / de-nitrification in addition to BOD and suspended solids removal [12].

S.No	Advantages	Disadvantages
1.	Single tank for the settling and reaction	High energy consumption
2.	Respond to the flow and load variations	High cost
3.	Low sludge production	Frequent sludge disposal
4.	No odour production	Difficult to adjust recycle time

3.4 Fluidized bed reactor

The fluidized bed reactor is the advanced attached growth process technique. It is a unique system to achieve outstanding removal of BOD, COD and nitrate from wastewater. This system is suited for both aerobic and anaerobic treatment systems [12]. Degradation of pollutant in fluidized bed reactor involves chemical reactions and liquid-solid-gas flow structures [13]. The reactor contains small media, such as sand and granular activated carbon, to which bacteria attach. The liquid which is to be treated is pumped through a small bed media with a sufficient velocity to cause fluidization. The attached biological growth takes place in the fluidized state and the biomass increases due to having a larger surface area. The aeration in the reactor is done by recalculating the liquid from the reactor to an oxygenator where air, or possibly oxygen, is bubbled. To overcome problems related to high re-circulation rates, when there is high oxygen demand in the reactor, the reactor might be aerated directly [20]. The basis for the use of fluidized bed systems is the immobilization of bacteria on solid surfaces. Many species of bacteria and other microorganisms have the ability for adhering to supporting matrices. A volume of Ring Pac media is immersed in water and is fluidized in the treatment reactor through the movement of gas and liquid. The media supports, the biomass concentration more than that achieved in activated sludge systems. This treatment is significantly more productive. The plastic media within each aeration tank provides a stable base for the growth of the microorganisms. The FBR process enables self-sustaining biological treatment; the need to periodically waste sludge and the requirement to supply a dilute return activated sludge to maintain an appropriate food to-microorganism (F/M) ratio is eliminated [12].

S.No	Advantages	Disadvantages
1.	Less HRT	Power consumption
2.	High resident biomass concentration	Less effective due to variation in inflow
3.	Less operation and maintenance cost	Septic conditions due to power failure
4.	Both attached and suspended growth takes place simultaneously	Constant monitoring of MLSS is require

3.5 Rotatory biological contactor (RBC)

A rotating biological contactor (RBC) is an attached growth bioreactor that offers an alternative technology to the conventional activated sludge process [19]. Rotating biological contactors (RBC) are consists of discs on which the microorganisms are get attached and degrade organic matter from the wastewater. The RBC media is arranged in a series of plates or discs which are rotated on a shaft through a motor. The rotation leads to mixing of wastewater through media/biofilm pores, compound diffusion to the film. Biological processes occur inside a fixed microbial biofilm, which contains active/non-active biomass. The RBC combines bacterial growth and substrate utilization with a natural biomass separation system [17]. The principal advantage of biofilm processes, such as RBCs, is that the mean cell residence time (MCRT) is uncoupled from hydraulic residence time (HRT). This allows higher organic loadings and resistance to shocks and toxicity than the suspended culture systems. The RBC biofilm is especially useful for the degradation of refractory agents due to high bacterial density and compound immobilisation. The presence of gradients can promote aerobic, anaerobic and anoxic conditions within a system, which promotes different removal regimes [18]. For some of the experiments the organic loading should be considered to evaluate the performance of the RBC process. RBC design is generally based on hydraulic loading [21]. Comparing with activated sludge process RBC is cost effective and less energy consumption, so small scale treatment plants can afford RBC. If the surface area decreases, the removal efficiency is also decreases. Therefore the disc submergence should be above 40% [22].

S.No	Advantages	Disadvantages
1.	High effluent quality	Require continuous electricity supply
2.	Less sludge production	High investment
3.	Compact units with small size	Odour occurs
4.	High shock loads resistance	Must be protected from sunlight, wind

Comparison between mostly used biological treatment technologies of pharmaceutical wastewater from hospitals [12]

Item description	MBR	ASP	SBR	FBR	RBC
Type of process	Suspended growth process with solid-liquid separation	Suspended growth process	Suspended growth process	Suspended & attached growth process	Attached growth process
Discharge of hospital wastewater standards(EPA)	pH:6.5–9.0 BOD_5<30mg/l COD<250mg/l TSS<100mg/l;	pH:6.5–9.0 BOD_5<30mg/l COD<250mg/l TSS<100mg/l;	pH:6.5 – 9.0 BOD_5<30mg/l COD<250mg/l TSS<100mg/l;	pH:6.5 – 9.0 BOD_5<30mg/l COD<250mg/l TSS<100mg/l;	pH:6.5 – 9.0 BOD_5<30mg/l COD<250mg/l TSS<100mg/l;
Pre-treatment and primary treatment	No need of clarifier	yes	No need of clarifier	No need of clarifier	Yes
Secondary clarifier	No	yes	No	Yes	Yes
BOD removal efficiency	99%	90%	95%-97%	95%-98%	94%
Sludge digestion	High	less	high	High	Less
Operation and maintenance problems	Difficult to control	Easy	Difficult to control	medium	Easy
Facing shock loads	Not effected	Not effected	Highly effected	Some problems	less effected

4. Conclusion

Pharmaceuticals are used to cure disease, but the increase in number of prescriptions, is creating an increase in the amount of pharmaceutical wastewater generated from hospitals. There are many numbers of techniques and technologies available for the treatment hospital wastewater. The reuse of wastewater gathered importance which is a sustainable therapy method by removing all the contaminants from the wastewater economically and safely. The government has to create new policies and guidelines to protect the public health and environment. The treatment of each biological technique has its own advantages and disadvantages. The comparison of the treatment technologies will help in the selection of suitable method for the management of pharmaceutical wastewaters from hospitals in terms of efficiency, operation, space requirement, energy, performance and cost.

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