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Waste Water Treatment Technologies - A Review

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Abstract— **By the year 2050 it is anticipated that the Earth's population will exceed 9 billion. To meet the basic needs of the population we need technology to deliver secure and safe sources of water for production of food and energy. Water reclamation, recycling, and reuse address these challenges by resolving water resource issues and creating new sources of high-quality water supplies. One of the most challenging aspects of a sustainable sewage treatment system design is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. This paper reviews various technologies of waste water treatment and describes the process of selection of suitable technology based on certain established criteria.**

Keywords—Waste water; treatment; technology;

I. INTRODUCTION

One of the most pervasive problems afflicting people throughout the world is inadequate access to clean water and sanitation [1]. By the year 2050 it is anticipated that the Earth's population will exceed 9 billion. To meet the basic needs of the population we need technology to deliver secure and safe sources of water for production of food and energy. [2]. Communities across the world face water supply challenges due to increasing demand, drought, depletion and contamination of groundwater, and dependence on single sources of supply. Water reclamation, recycling, and reuse address these challenges by resolving water resource issues and creating new sources of high-quality water supplies [3]. There exist a number of significant barriers and impediments to the widespread implementation of water reuse. These include the need for innovative technologies, technology transfer, and novel applications; the need for public education and increased public acceptance; lack of available funding for water reuse projects; and the need for support by suitable legislations and regulations. One of the most challenging aspects of a sustainable sewage treatment system design is the analysis and selection of the treatment processes and technologies capable of meeting the requirements. The process is to be selected based on required quality of treated water. Other than the cost of treatment, effluent quality, process complexity, process reliability, environmental issues and land requirements should also be evaluated and weighted in selecting the suitable technology. This paper is a compilation of the literature review conducted on various technologies of waste water treatment available today, and describes the process of selection of suitable technology based on certain established criteria.

II. TECHNOLOGIES OF WASTE WATER TREATMENT

Waste water treatment is performed by adopting different processes. The processes have been classified according to removal of various constituents from waste water. These involve removal of - organic and inorganic, colloidal and suspended solids, dissolved organic constituents, dissolved inorganic constituents and biological constituents.

A. *Activated Sludge Process*

Activated Sludge Process (ASP) is the most common suspended growth process used for waste water treatment. In this process, waste water containing organic matter is aerated in an aeration basin in which micro-organisms metabolize the suspended and soluble organic matter. Part of organic matter is synthesized into new cells and part is oxidized to CO_2 and water to derive energy. In activated sludge systems the new cells formed in the reaction are removed from the liquid stream in the form of a flocculent sludge in settling tanks. A part of this settled biomass, described as activated sludge is returned to the aeration tank and the remaining forms waste or excess sludge (Refer Fig. 1)

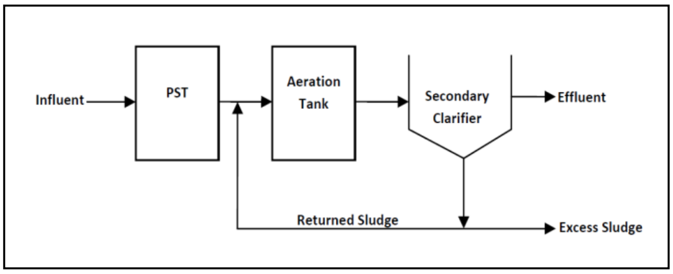

Fig. 1: Schematic of Activated Sludge Process

Activated sludge plant involves:

1. Waste water aeration in the presence of a microbial Suspension
2. Solid-liquid separation following aeration
3. Discharge of clarified effluent
4. Removal of excess biomass, and
5. Return of remaining biomass to the aeration tank.

It is provided with primary clarifier to reduce the organic load in biological reactor (aeration basin). About 40% of organic load is intercepted in primary clarifier in the form of sludge, decreasing the loading in the aeration tank. Detention period in aeration tank is maintained between 4 to 6 h. After aeration tank, the mixed liquor is sent to secondary clarification where sludge and liquid are separated. A major portion of the sludge is re-circulated and excess sludge is sent to a digester.

In case if the sludge generated in primary clarifier and excess sludge from secondary clarifier are not matured, digestion of such sludge is essential before disposal. In anaerobic sludge digestion, such sludge produces biogas which can be used for power generation by gas engines. Generated power can be used for operation of plant [4].

B. Moving Bed Bio Reactor

Moving Bed Biofilm Reactor is an aerobic attached biological growth process. It does not require primary clarifier and sludge recirculation. Raw sewage, after screening and degritting, is fed to the biological reactor. In the reactor, floating plastic media is provided which remains in suspension. Biological mass is generated on the surface of the media. Attached biological mass consumes organic matter for their metabolism. Excess biological mass leaves the surface of media and it is settled in clarifier. Usually a detention time of 5 to 12 h is provided in the reactors (Refer Fig. 2).

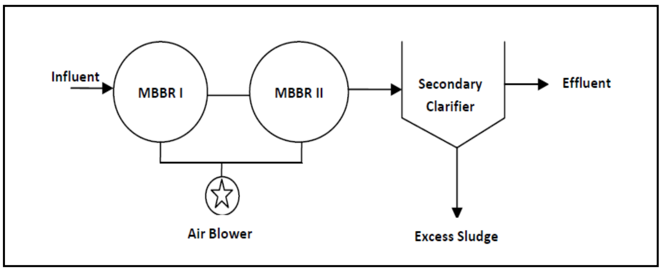

Fig. 2: Schematic of MBBR

MBBR utilizes the whole tank volume for biomass growth. It also has a very low head-loss. Contrary to the activated sludge reactor, it does not need any sludge recycle. This is achieved by having the biomass grow on carriers that move freely in the water volume of the reactor and that are kept within the reactor volume by a sieve arrangement at the reactor outlet. The reactor may be used for aerobic, anoxic or anaerobic processes [5].

C. Sequencing Batch Reactor

Sequencing Batch Reactor (SBR) is a fill and draw type activated sludge system. In this system waste water is added to a single batch reactor, treated to remove undesirable components, and then discharged. The conventional activated sludge system and SBR process are the same but the difference between the two technologies is that the SBR performs equalization, biological treatment and secondary clarification in a single tank using time controlled sequence. Equalization, aeration, and clarification can be achieved using a single batch reactor (Refer Fig. 3).

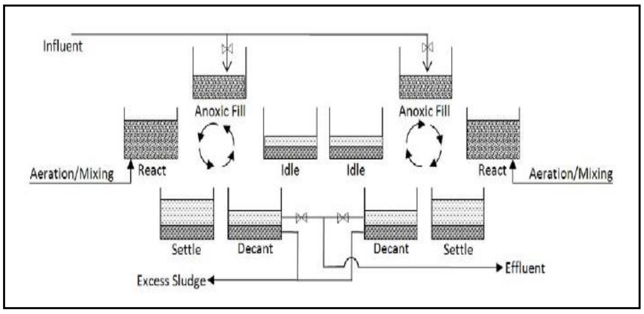

Fig. 3: Schematic of SBR

The sequential batch reactor (SBR) process is a cyclic activated sludge treatment process. Multiple reactors are provided to treat the wastewater in batches. Sequencing batch reactors will be operated to oxidize carbonaceous BOD, nitrify the ammonia and denitrify to reduce total nitrogen to a level that meets the permit limits. All treatment processes including equalization, aeration, denitrification, and sedimentation and decanting occur in the SBRs eliminating the need for separate clarification and return activated sludge systems [6].

All the SBR systems have five steps in common, which are carried out in sequence as follows.

Fill: waste water flows in to the reactor and mixes with the biomass already present in the reactor. Filling of influent can be varied to create the condition like static fill, mixed fill, and aerated fill

React: Depending on the conditions applied: anaerobic, anoxic or aerobic reactions, substrate present in the waste water are consumed by the biomass.

Settle: After sufficient time of reaction, aeration and mixing is stopped and biomass is allowed to settle from the liquid resulting in clear supernatant.

Decant: Clear supernatant (treated waste water) is removed from the reactor.

Idle: This is the time between cycles which is used to prepare the SBR for next cycle. It is also used to adjust the cycle time between the SBR reactors. Sludge wasting is also performed during this phase.

D. Up-flow Anearobic Sludge Blanket

Nowadays, carbon emission and therefore carbon footprint of water utilities is an important issue. In this respect, we should consider the opportunities to reduce carbon footprint for small and large wastewater treatment plants. The use of anaerobic rather than aerobic treatment processes would achieve this aim because no aeration is required and the generation of methane can be used within the plant. High-rate anaerobic digesters receive great interests due to their high loading capacity and low sludge production. Among them, the upflow anaerobic sludge blanket (UASB) reactors have been most widely used [7]. Upflow Anaerobic Sludge Blanket (UASB) is an anaerobic process in which influent waste water is distributed at the bottom of the reactor and travels in an up-flow mode through the sludge blanket. Critical components of UASB design are the influent distribution system, the gas-liquid-solid separator (GLSS) and effluent withdrawal design. Compared to other anaerobic processes, UASB allows the use of high hydraulic loading (Refer Fig. 4).

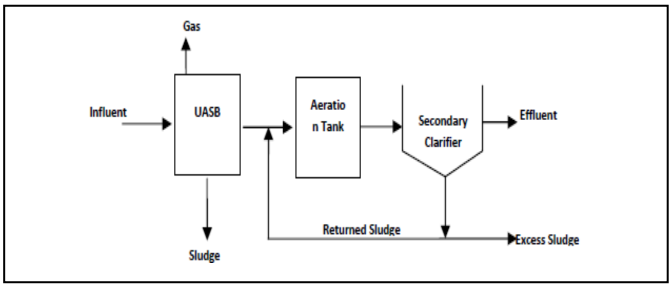

Fig. 4: Schematic of UASB

E. Membrane Bio Reactor

Membrane bioreactor (MBR) technology, which combines biological-activated sludge process and membrane filtration has became more popular, abundant, and accepted in recent years for the treatment of many types of wastewaters, whereas the conventional activated sludge (CAS) process cannot cope with either composition of wastewater or fluctuations of wastewater flow rate. MBR technology is also used in cases where demand on the quality of effluent exceeds the capability of CAS. Although MBR capital and operational costs exceed the costs of conventional process, it seems that the upgrade of conventional process occurs even in cases when conventional treatment works well. It can be related with increase of water price and need for water reuse as well as with more stringent regulations on the effluent quality. Along with better understanding of emerging contaminants in wastewater, their biodegradability, and with their inclusion in new regulations, MBR may become a necessary upgrade of existing technology in order to fulfill the legal requirements in wastewater treatment plants (WWTPs) [8].

Membrane Bio Reactors (MBR) for waste water treatment is a combination of a suspended growth biological treatment method, usually activated sludge, with membrane filtration equipment, typically low-pressure microfiltration (MF) or ultra filtration (UF) membranes. The membranes are used to perform the critical solid-liquid separation function. In activated sludge facilities, this is traditionally accomplished using secondary and tertiary clarifiers along with tertiary filtration. It is a biological reactor with a suspended biomass. The solid-liquid separation in membrane bioreactor is achieved by a microfiltration membrane with pore sizes ranging from 0.1 to 1.0 µm. No secondary clarifier is used and has the ability to operate at high MLSS concentrations. Air is introduced through integral diffusers to continually scour membrane surfaces during filtration, which facilitate mixing and in some cases, to contribute oxygen to the biological process. (Refer Fig. 5)

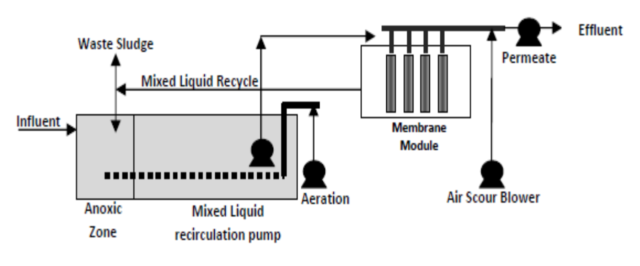

Fig.5: Schematic of MBR

III. COMPARATIVE ANALYSIS OF TECHNOLOGIES

In the process of choosing the most suitable technology, it is necessary to compare different features of the technologies as well as their performance.

The following table (Table I) gives the important considerations for selection of waste water treatment processes.

The pros and cons of technologies are compared against the weighted significance of each of the criteria. The following table (Table II) gives a comparative analysis of the technologies that were described in the previous section.

TABLE I: SEWAGE TREATMENT PROCESS SELECTION CONSIDERATION

Consideration	Goal
Quality of treated Sewage	Production of treated water of stipulated quality without interruption
Power requirement	Reduce energy consumption
Land required	Minimize land requirement
Capital Cost of Plant	Optimum utilization of capital
Operation & Maintenance costs	Lower recurring expenditure
Maintenance requirement	Simple and reliable
Operator attention	Easy to understand procedures
Reliability	Consistent delivery of treated sewage
Resource Recovery	Production of quality water and manure
Load Fluctuations	With stand variations in organic and hydraulic loads

TABLE II: COMPARISON OF WASTE WATER TREATMENT TECHNOLOGIES IN TERMS OF SIGNIFICANT PARAMETERS

Parameter	ASP	MBBR	SBR	UASB	MBR
BOD, mg/l	<30	<20-30	<5	<30	<3-<5
COD, mg/l	<250	<250	<100	<250	<100
TSS, mg/l	<100	<100	<10	<100	<5
TKN &P mg/l	NT*	NT*	<10 - <2	NT*	NT*
Area, Acres	10.9	5.5	6.3	15.6	5
Capital Cost Rs. Lac (100MLD)	6000	7000	8000	6500	25000
Power cost Rs/m3	1.71	1.8	1.14	1.11	3.0
Chemical Cost	0.07	0.07	0.06	0.07	0.50
Maintcost Rs./m3	0.22	0.25	0.27	0.22	1.1
Power generation	Nil	Nil	Nil	Yes	Nil

NT: No Treatment

A comprehensive analysis portraying the positive aspects of the most important factors is performed to get the following result as given in Table III [9].

TABL III: TECHNOLOGY ASSESSMENT FOR SEWAGE TREATMENT PLANT

Criteria	ASP	MBBR	SBR	UASB	MBR
Quality of Treated Effluent	🟨	🟨	🟩	🟨	■
Nutrient Removal potential	🟥	🟥	🟩	🟥	🟨
Low Land Requirement potential	🟨	🟩	🟩	🟥	🟩
Low Capital Cost potential	🟩	🟨	🟨	🟩	🟥
Low Power Requirement Potential	🟨	🟨	🟩	■	🟥
Electricity generation potential	🟥	🟥	🟥	🟨	🟥
Low O & M Skills Potential	🟩	🟩	🟨	🟩	🟥
🟥 **Low**	🟨 **Medium**		🟩 **High**		■ **V. High**

IV. SELECTION OF TECHNOLOGY

Selection of technology for waste water treatment depends on the following parameters:

1. The use to be made of treated effluent
2. Nature of waste water
3. Compatibility of treatment process
4. Available means of ultimate disposal of contaminant
5. Environmental and economic feasibility

The use of treated effluent, for example for drinking or cooking, demand the extent of treatment required to be very high, so that whatever constituents present in the system will have to be removed. The nature of waste water refers to the characteristics of the influent that in turn depends on the constituents in the waste water or its level of contamination.

Compatibility of treatment process refers to the suitability of a process for a particular circumstance or particular type of waste water. Similarly the available means of ultimate disposal of contaminants is also important since many of treatment technology generate some secondary pollutants which need further attention for their safe disposal. The environmental feasibility refers to the impact of a particular technology on the environment in terms of the pollution that it creates during its operation or due to the storage or disposal of the generated waste. The economic feasibility is also important as the cost involved in getting the effluent of the required quality would decide whether it is worth adopting a particular technology.

V. CONCLUSION

Water recycling and reuse has been recognized as a key approach to alleviate water shortage. It is understood that one fourth of global population faces economic water scarcity resulted from poor management of the sufficient available water resources. Hence proper management in water recycling and reuse is required to provide the best solution to water crisis. The conventional methods used for the treatment of waste water do not provide the effluent of the required quality. It is therefore required to employ advanced waste water treatment methods which would significantly improve the performance of treatment plants and the production of high quality effluent suitable for various reuse applications. Various advanced technologies such as ASP,MBBR, SBR, MBR and UASB have been studied and an analysis of these methods in terms of their performance to achieve certain criteria has been presented. Serving the world population with adequate drinking water and sanitation is an important prerequisite, not only to hygienic safety, but also to prosperity. Hence to meet the basic needs of the population which is anticipated to be more than 9 billion by the year 2050, technological advancement in water recycling and reuse which will surely deliver secure and safe sources of water for production of food and energy, is imminent.

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