STUDY OF WIDELY USED TREATMENT TECHNOLOGIES FOR HOSPITAL WASTEWATER AND THEIR COMPARATIVE ANALYSIS

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ABSTRACT

Hospital wastewater may contain various potential hazardous materials. Indeed hospital wastewater may have an adverse impact on environments and human health. Therefore, the selection of suitable treatment technology and proper treatment of hospital wastewater is essential. Various study and research work reveals that quality of hospital wastewater is similar to medium strength values of the domestic wastewater, The discharge standards for hospital wastewater should conforms to EPA 1986 (Source :GSR 7 dated Dec.22, 1998). The tolerance limit for sewage effluent discharged into surface water sources will be as per BIS standards IS: 4764:1973. According to WHO guidelines, treated wastewater should not contain no more than one helminths egg per litre and no more than 1000 faecal coli forms per 100 mL, if is to be used for irrigation. A study of various treatment technologies has been carried out along with their advantages and disadvantages. The comparison of widely used treatment technologies will help designers, engineers, architects, economists in selection of treatment technologies in terms of their efficiency, energy, operation , performance, land requirement, cost etc. Effluent discharge or re-use after suitable treatment protects environment and public health, government shall have to adapt integrated wastewater management approach, monitor and enforce existing present standards and also if require can generates new guidelines or policies or standards.

KEYWORDS: *Wastewater, Hospital, BOD5, Hospital Wastewater, SBR, Treatment Technologies, SAFF.*

I. INTRODUCTION

Wastewater composition refers to the actual amounts of physical, chemical and biological constituents present in wastewater. Depending upon the concentration of these constituents, domestic wastewater is classified in strong, medium or weak. Various study and research work reveals that monitoring of pH, BOD, COD, TSS and total coli forms indicated that the quality of hospital wastewater is similar to medium values of the domestic wastewater. Hospital wastewater may contain various potential hazardous materials including, microbiological pathogens, radioactive isotopes, disinfectants, drugs, chemical compounds and pharmaceuticals. Indeed the hospital wastewater may have an adverse impact on environments and human health. Therefore, the selection of suitable treatment technology and proper treatment of hospital wastewater is essential. There is need to develop a comparison of widely used treatment technologies for hospital wastewaters with respect to their design, land requirement, efficiency, operation & maintenance (O&M), fixed and variable costs, advantages & disadvantages etc.

On- site treatment of hospital wastewater will produce a sludge that contains high concentrations of helminths and other pathogens. According to the relevant WHO guidelines, treated wastewater should not contain no more than one helminthes egg per litre and no more than 1000 faecal coli forms per 100 mL if is to be used for irrigation.

Under the Environmental (Protection) Act 1986, the effluent limits are applicable to those hospitals which are either connected to sewer without terminal sewage treatment plant or not connected to public sewer. The discharge standards for hospital wastewater should conforms to EPA 1986 (Source: GSR 7 dated Dec.22, 1998).The tolerance limit for sewage effluent discharged in India is as per BIS standards IS: 4764:1973. Most of the countries have their own standards for sewage disposal & reuse of reclaimed wastewater after suitable treatment.

There is need to encourage environmental engineers, technologist, economists should develop & analysis for different treatment technologies on efficiency, design aspects, operational aspects, financial aspects and overall risks associated with treatment technologies.

The various treatment technologies have been developed so far for treatment of hospital wastewater. Some of these treatment technologies include Activated Sludge Process (ASP), Extended Aeration (E.A.), Sequential Batch Reactor (SBR), Fluidized Bed Reactor (FBR), Submerged Aeration Fixed Film (SAFF) Rector and Membrane Bio-Reactor (MBR).

ASP is very old technology and development of more users' friendly similar kind of technology has made activated sludge process an obsolete technology for the treatment of sewage.

E.A. is exactly the similar kind of treatment technology like ASP except more hydraulic retention time to give extended aeration for the complete digestion of organic matter.

SBR is also similar treatment technology like E.A. system but in one tank only where both biodegradation as well as settling of solids and removal of sludge is done from same tank. It is also known as a draw-and-fill activated sludge treatment system.

FBR is the latest advance in attached as well as suspended growth aerobic biological treatment technology. Influent is treated through a bed of small ring pac media at a sufficient velocity to cause fluidization in a reactor.

SAFF is also a latest advancs in attached growth process and has been implemented in recent years as fixed film media into activated sludge reactors to improve performance of sewage treatment plants.

MBR is also used to treat wastewater which works on the principle of filtration of activated sludge through the concept of using flat sheet type or hollow fibre type submerged membrane modules in bioreactors.

A brief description of each technology, advantages, disadvantages and their comparative analysis is given below:

1.1. Activated Sludge Process

This is a conventional process to treat the hospital wastewater. In this process the wastewater is treated in open tank called aeration tank and air is supplied either through fixed / floating surface aerator or air blower to provide oxygen for the aerobic microbes. Around 12-15 hour hydraulic retention time is provided for the treatment of wastewater. The microorganisms utilize the oxygen in the air and convert the organic matter into stabilized, low-energy compounds such as NO_3, SO_4, and CO_3 and synthesize new bacterial cells. The overflow carried to the adjacent clarification system contains active microbes and is required to be recycled back to aeration tank to maintain specified critical performance rating parameter like MLSS and F/M ratio.

A number of different modifications or variants of the activated sludge process have been developed since the original experiments of Arden and Lockett in 1914. These variants, to large extent, have been developed out of necessity or to suit particular circumstances that have arisen.

Generally two type of mixing regime are the major interest in the activated sludge process; plug flow and complete mixing. In the first one, the regime is characterized by orderly flow of mixed liquor through the aeration tank with the no element of mixed liquor or mixing along the path of flow. In the complete mixing, the contents of aeration tank are well stirred and uniform throughout. Thus at steady state, the effluent from the aeration tank has the same composition as the aeration tank contain.

The biological component of the activated sludge system is comprised of microorganisms. The composition of these microorganisms is 70 to 90 percent organic matter and 10 to 30 percent inorganic matter. Bacteria, fungi, protozoa, metazoa and rotifers constitute the biological mass of activated sludge. However, the constant agitation in the aeration tanks and sludge recirculation are deterrents to the growth of higher organisms.

The species of microorganism that dominates a system depends on environmental conditions, process design, the mode of plant operation, and the characteristics of the secondary influent wastewater. The microorganisms that are of greatest numerical importance in activated sludge are bacteria. Some bacteria are strict aerobes (they can only live in the presence of oxygen), whereas others are anaerobes (they are active only in the absence of oxygen). The preponderance of bacteria living in activated sludge are facultative—able to live in either the presence or absence of oxygen, an important factor in the survival of activated sludge when dissolved oxygen concentrations are low or perhaps approaching depletion.

While both heterotrophic and autotrophic bacteria reside in activated sludge, the former predominate. Heterotrophic bacteria obtain energy from carbonaceous organic matter in influent wastewater for the synthesis of new cells. At the same time, they release energy via the conversion of organic matter into compounds such as carbon dioxide and water. Important genera of heterotrophic bacteria include Alcaligenes, Arthrobacter, Citromonas, Flavobacterium, Pseudomonas, and Zoogloea.

ASP is very old technology and has been used extensively in all the places for the treatment of wastewater because of non-availability of any other technology. The development of more users' friendly similar kind of technology has made activated sludge process an obsolete technology for the treatment of sewage.

1.1.1. Advantages

- BOD_5 removal efficiency $\geq$ 90%.
- User friendly.
- Require less skilled labour for operation and maintenance (O&M).
- Oxidation and nitrification achieved without chemicals.
- Maximum removal of suspended solids up to 97%.
- Most widely used wastewater treatment process because of non-availability of any other technology.
- Moderate land area.
- Ability to handle peak load and dilute toxic substances.

1.1.2. Disadvantages

- More sludge volume without getting well settled.
- Inefficient in color removal from wastewater and may increase the color through formation of highly coloured intermediates through oxidations.
- Poor effluent quality with odor problem.
- More sensitive to shock loading and temperature.
- Inefficient in the nutrients removal from wastewater and tertiary treatment is required for further polishing.
- Larger volume and high aeration costs.
- Not much operational flexibility.
- Biomass instabilities like sludge bulking.
- High effluent TSS & chlorine demand.
- High energy used.
- Considered an obsolete technology because of advancement of other user friendly treatment processes.

1.2. Extended Aeration (E.A.) Process

It is exactly similar kind of treatment technology like activated sludge process except more hydraulic retention time to give extended aeration for the complete digestion of organic matter. Normally 18-24 hour retention time is provided in the aeration tank for the complete aerobic biodegradation. The main

objective behind increasing the hydraulic retention time is to reduce the odor problem because of semi digested sludge and reducing the percentage of sludge recycling to the aeration tank. This technology is ideally suited to the large installation where space is not a constraint.
Extended aeration is a reaction – defined mode rather than a hydraulically defined mode, and can be nominally plug flow or complete mix. This process can be sensitive to sudden increase in flow due to resultant high MLSS loading to final clarifier, but is relatively insensitive to shock loadings in concentration due to buffering effect of the large biomass volume. In this process at a low organic loading, long aeration time, high MLSS concentration and low F/M, the BOD removal efficiency is high because of high detention in the aeration tank, the mixed liquor solid undergo considerable endogenous respiration and get well stabilized. The excesses sludge dose not requires separate digestion either can be directly dried on sand beds or treated through centrifuge / filter presses.

1.2.1. Design Consideration

The design considerations in the design of extended aeration process are design parameters / operating characteristics, aeration tank capacity and dimensions, aeration facilities etc.

1.2.1.1. Design Parameters / Operating Characteristics

The design parameters and operating characteristics includes BOD_5 removal efficiency, F/M ratio, SRT, detention time, O_2 requirements, MLSS, waste sludge etc.

Table-1: Common Design Parameters and Operating Characteristics of Extended Aeration Technology

S.No.	**Design Parameters / Operating Characteristics**	**Range**
1.	F/M (lb BOD_5/lb MLSS.d)	$\leq$ 0.05
2.	SRT (days)	$\geq$30
3.	lbBOD_5/1000cu ft.d	10-15
4.	BOD_5 Removal (%)	90+
5.	Aerator Detention Time (h)	16-24
6.	Nitrification Occurs	Yes
7.	O_2 Requirements (lb/ lb BOD_5 Removed)**	1.4-1.6*
8.	Re-circulated Underflow Solid Rate (% Q)	100-300
9.	MLSS (mg /l)	2000-6000
10.	O_2 Uptake (mg/g.h MLSS)	3-8
11.	Waste Sludge (lb/lb BOD_5 Removed)	0.15-0.3

Note- * Additional oxygen must be added if nitrification takes place.
** Density of O_2 @ 0^0C and 760 mm = 0089 lb/cu ft (1.429 g/l).
MLSS = 1000 mg/l;
MLSS x 0.8 = MLVSS
lb /1000 cu ft x 4.883 = g/m^2

1.2.1.2. Aeration Tank Capacity and Dimensions

The volume of aeration can be calculated from the following equation:

$$F/M = [Q (S_o-S)] / [XV]$$

Where,

Q = Volumetric flow rate (m^3/day)
X = MLSS concentration (mg/1)
V = Volume of tank (m^3)
F/M = Food to mass ratio.
S_o, S = Soluble food concentration in the effluent and rector respectively (mg/l).

The dimensions of the aeration tank depend on the type of aeration equipment employed. The depth controls the aeration efficiency and usually kept between 3 to 10 m. The width controls the mixing and usually kept between 1.2 to 2.2 m. The length should be not be less than 30 or not ordinary longer than 100m. The horizontal velocity should be around 1.5m/s. tank free board is generally kept between 0.3 and 0.5m. The inlet should be design to maintain a minimum velocity of 0.2 m/s to avoid the deposition of solids.

1.2.1.3. Oxygen Requirement and Aeration Facilities

Oxygen is required in the extended aeration process for the oxidation of a part of the influent organic matter and also for the endogenous respiration of micro-organism in the system. The total oxygen requirement of the process may be formulated as follows:

$O_2 = [Q\ (S_o - S_e)] / f] - [1.42\ Q_w\ X_r]$------ (i)

Where,

f = ratio of BOD5 to ultimate BOD
Q = Volumetric flow rate (m3/day)
S_o, S_e = Soluble food concentration in the influent and effluent respectively (mg/l).
Q_w = Waste activated sludge rate (m^3/day)
X_r = MLSS concentration in return sludge (mg/1) and
1.42 = oxygen demand of biomass (g/g).

The above equation (i) may be expressed as

$O_2 = [Q\ (S_o - S_e)] /f]-[1.42(VX / \theta_c)]$ ---- (ii)

Where,

X = MLSS concentration in reactor (mg/1)
V = Volume of tank (m^3)
θ_c = SRT or Mean cell resident time (day)

Note- The formula does not allow for nitrification but allows only for carbonaceous BOD removal.
The aeration facilities are designed to provide the calculated oxygen demand of the wastewater against a specific level of dissolved oxygen in the waste water.
Various air diffusing device have been classified as either fine bubble or coarse bubble, with the fine bubble are more efficient in transferring oxygen.
A diffused-air system consists of diffuser that are submerged in the waste water, header, pipe, air mains, and the blower and appurtenances through which the air passes. It consists of a tank with perforated pipes, tubes or diffuser plates, fixed at the bottom to release fine air bubbles from compressor unit.
Aerator has following advantages:

- Aerator are rated based on the amount of oxygen they can transfer to the water under standard condition of 20ºC, 760 mm Hg barometric pressure and zero D.O.
- Aeration removes odour and tested due to volatile gases like hydrogen sulphide and due to algae and related organisms.
- Aeration also oxidize Fe and Mn, increase dissolved oxygen contain in water, remove CO_2 and reduces corrosion and remove methane and other flammable gases.

1.2.2 Advantages

- Low sludge yields.
- Operation is rendered simple due to elimination of primary settling and separate sludge digestion.
- Easy to install.
- Require less skilled labour for operation and maintenance (O&M).
- Surface aerators in open tanks with long detention periods are not advisable for severe climates
- Efficiency and effluent quality is better than conventional ASP process.
- Odor free.

1.2.3 Disadvantages

- Oxygen requirement for the processes is higher and running cost is also therefore high.
- Loss of pinpoint floc and the tendency to loss solids following low loadings.

- Unable to achieve de-nitrification or phosphorus removal.
- Limited flexibility in response to changing effluent requirements.
- Long aeration time combined with long sedimentation rate may also result is rising sludge in the sedimentation tank.
- Low temperature insensitive if heat loss is not controlled.
- Larger footprint / land area required.
- Large energy requirements.

1.3. Sequential Batch Reactor (SBR)

The first notable, but short lived, resurgence of interest in biological treatment occurred in the early 1950s when Porges (1955) and his co-workers first studied batch operation of ASP system for treating wastewaters. The second resurgence occurred in the 1970s with the effort of Irvine and with his co-workers investigating the suitability of batch biological processes (Denneis et all, 1979; Irvine et al, 1977; Irvine and Richter, 1976). Around the same period, interest in the batch operated biological treatment systems surfaced also in Australia (Goronszy, 1979).

It is the same treatment technology like Extended Aeration (E.A.) system but in one tank only where both biodegradation as well as settling of solids and removal of sludge is done from same tank. It is also known as a draw-and-fill activated sludge treatment system. The wastewater flows from one tank to another tank on a continuous basis and virtually all tanks have a predetermined, periodic operating strategy. Therefore, the SBR is considered a time-oriented and batch process system. The essential difference between the SBR and the conventional continuous flow activated sludge system is that SBR carries out functions such as equalization, aeration and sedimentation in a timer rather in a space sequence.

It consists of a single or multiple reactor tanks operating in parallel. Each operating cycle of a SBR reactor comprises five distinctive phases, referred to as: FILL, REACT, SETTLE, DRAW and IDLE phases. The overall control of the system is accomplished with level sensors and timing device or microprocessor.

One advantage of this orientation is flexibility of operation. The total time in the SBR is used to establish the size of system and can be related to the total volume of a conventional continuous-flow facility. As a result, the fraction of time devoted to a specific function in SBR is equivalent to some corresponding tank in a space oriented system. Therefore the relative tank volumes dedicated to , say aeration and sedimentation in the SBR can redistributed easily by adjusting the mechanism which controls the time (and , therefore share the total volume) planned for either function. In conventional ASP, the relative tank volume is fixed and cannot be shared or redistributed as easily as in SBR.

Because of the flexibility associated with working in time rather that is space, the SBR can be operated either as labour – intensive, low- energy, high sludge yield can also be traded off with initial capital costs. The operational flexibility also allows designers to use SBR to meet many different treated objectives, including one objective at the time of construction (e.g. BOD and suspended solids reduction) and another at a later time (e.g. nitrification / de-nitrification in addition to BOD and suspended solids removal).

1.3.1 Advantages

- Single tank for reaction and settling.
- True batch mode of operation & can be operated as a time-based control system allowing continuous inflow of wastewater during all phases of the cycle.
- Respond to flow and load variations.
- Quiescent settling and no sludge storages.
- Ability to achieve biological oxidation, nitrification, de-nitrification, phosphorus removal and solid/liquid separation.
- Large operational flexibility and automatic possible.
- Minimal sludge bulking.
- Computer interface technologies, and advanced monitoring instrumentation capability, and ability to be operated remotely.
- Eliminates primary, secondary clarifiers and return sludge pumps
- Small footprint required.

- Less labour required when operated automatically and computer controlled.
- Odor free technologies.

1.3.2 Disadvantages

- Higher energy consumptions
- Difficulty to adjust cycle time.
- Frequent sludge disposal.
- Special decanting and aeration equipments (can't use diffusers in reaction tank)
- Need to recycle early decant if solids in weir trough.
- Setting system sequences can be complex, especially if anoxic de-nitrification is required.
- Use of an anaerobic chamber, which is a potential odor source and is an area where corrosion may occur, even in a concrete tank.
- Higher cost because of automation involved.
- Skilled labour is required.

1.4. Fluidized Bed Reactor (FBR)

The FBR process is the latest advance in attached growth aerobic biological treatment technology. FBR employs RING PAC MEDIA, neutrally buoyant bio film carrier elements, to achieve outstanding BOD/COD removal productivity from a compact bioreactor.

In Fluidized Bed Reactors, the liquid to be treated is pumped through a bed of small media at a sufficient velocity to cause fluidization. In the fluidized state the media provide a large specific surface for attached biological growth and allow biomass concentrations in the range 10-40 kg/m3 to develop (Cooper and Sutton, 1983). For aerobic treatment processes the reactor is aerated. This is done by recalculating the liquid from the reactor to an oxygenator where air, or possibly oxygen, is bubbled (Cooper, 1981). To overcome problems related to high re-circulation rates, needed when there is high oxygen demand in the reactor, the reactor might be aerated directly.

The basis for the use of fluidized bed systems is the immobilization of bacteria on solid surfaces. Many species of bacteria (and also other microorganisms) have the ability for adhering to supporting matrices.

In this process, a volume of Ring Pac media is immersed in water and is fluidized (kept in constant motion) through the movement of gas and liquid in the treatment reactor. As the media supports a biomass concentration several times that achievable in activated sludge systems, treatment is significantly more productive. Refer figure-1 for ring pac bio-media.

Figure-1: Ring Pac Bio-Media for FBR reactors

The neutrally buoyant plastic media within each aeration tank provides a stable base for the growth of a diverse community of microorganisms. PVC media has a very high surface-to-volume ratio, allowing for a high concentration of biological growth to thrive within the protected areas of the media. 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.

In addition, the excess biomass is automatically sloughed off in the process, maintaining a highly active biomass.

1.4.1. Advantages

- The FBR requires very less hydraulic retention time (HRT) compared to an extended aeration or activated sludge process to perform the same BOD reduction duty.
- High resident biomass concentration, intense mass transfer conditions and aggressive biomass-sloughing action enable the process to rapidly respond to variations in process load.

- The mechanical simplicity, flow-through nature of the process and no sludge problems all result in an almost operator-free process.
- FAB reactor is hybrid reactor where attached growth and suspended growth activity take place simultaneously.
- The BOD removal rate continues to increase with loading rate even at loading rates in excess.
- Less operation and maintenance cost during plant operations.
- Less footprint area required for installation.
- Efficient and reliable technology.

1.4.2 Disadvantages

- Less effective during large variation in influent wastewater.
- Constant monitoring of MLSS is required.
- More chances of septic conditions due to power failure.
- Moderate power consumption.

1.5 Submerged Aeration Fixed Film (SAFF) Reactor

An innovation that has been implemented in recent years is the fixed film media into activated sludge reactors to improve performance and in some cases to minimize expansion of existing facilities. In plants where nitrification and de-nitrification is practiced, nitrification is usually the rate-limiting step and the media is placed in the aerobic zone to enhance nitrification at low temperatures.

It is based on aerobic attached growth process and used in the secondary treatment of wastewater treatment plant. In this process raw sewage is introduced into the SAFF Reactor where for attached growth process takes place containing contains polymer based bio-media. The aerobic environment in the SAFF is achieved by the use of fine bubble diffused aeration equipments, which also serves to maintain the mixed liquor in a completely mixed regime. The mixture of new cells and old cells overflows into a secondary sedimentation tank where the cells are separated from the treated wastewater. A portion of the settled cells is recycled using the horizontal, non-clog, and flooded pumps to maintain the desired concentration of organisms in the SAFF reactor and the remaining portion is wasted to aerobic sludge digester-cum-thickener tank for further sludge treatment. Refer figure-2 for general sketch for SAFF reactor system.

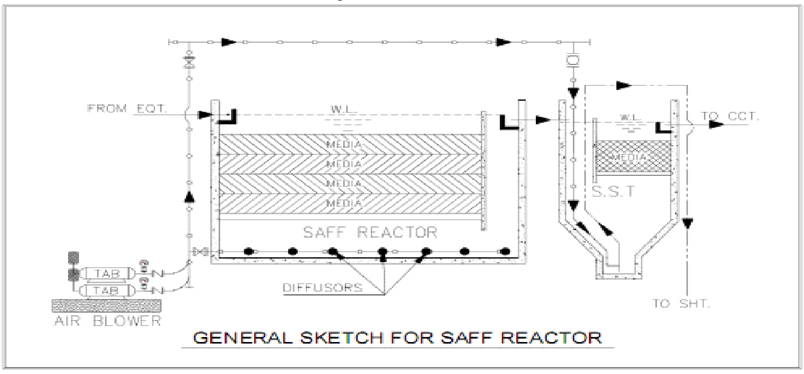

Figure-2: General sketch for SAFF reactor

SAFF technology for optimum performance and dependability. Using reliable, cost effective and energy efficient blower for aeration are with an integral flow management system and enter the biological treatment stage where it is aerated with fine bubble membrane diffuser. The continuous supply of oxygen together with the incoming food sources encourage microorganism to grow on the surface of the submerged media, convening the waste water in to CO_2 and water in the process. Media of SAFF is providing more surface area for microorganism to grow. Excess micro-organism (known as humus solids) that flows out of the biological treatment stage is separated from the final effluent in another settlement stage.

1.5.1. Advantages

- No constant monitoring of MLSS required thus making it user friendly.
- No chance of occurring septic conditions due to power failure as it sustains microbial growth under irregular power supply conditions.
- Reduced overall volume due to multistage.

- Reduced civil constructions.
- Less maintenance as there is no moving parts.
- Low power consumption due to high oxygen transfer.
- Better oxygen transfer.
- Less sludge generation hence reduced problem of sludge disposal.
- Low operating costs due to absence of sludge recycling.
- The fixed-film process will continually slough off outer layer(s) of dead bio film and continue to produce new microorganisms to meet the organic load.

1.5.2. Disadvantages

- Little higher footprint compared to FBR technology.
- Excess sludge in the SAFF reactor can clog the bio-media, therefore continuous monitoring of MLSS is required.

1.6. Membrane Bio-Reactor (MBR)

It is latest technology has been using very widely to treat domestic wastewater. In this process the treatment is using by synthetic membranes or diffusion process through membrane.

It is proposed to use Membrane Bio-Reactor (MBR) system working on the principle of filtration of activated sludge through the concept of using flat sheet type or hollow fibre type submerged membrane modules in bioreactors. The membranes in a MBR system are made from polymeric organics (PVDF, PE or PES) and assembled into units (modules, cassettes, stacks) with high packing density. Raw wastewater pre-treatment is important to sustain stable MBR performance and fine screening is essential operation.

The use of Membrane Bio-Reactors (MBRs) in municipal wastewater treatment has grown widely in the past decades. The MBR technology combines conventional activated sludge treatment with low-pressure membrane filtration, thus eliminating the need for a clarifier or polishing filters. The membrane separation process provided a physical barrier to contain microorganisms and assures consistent high quality reuse water. The ability to treat raw wastewater for reuse provides a new, reliable, drought-proof supply of water that can be benefit to communities.

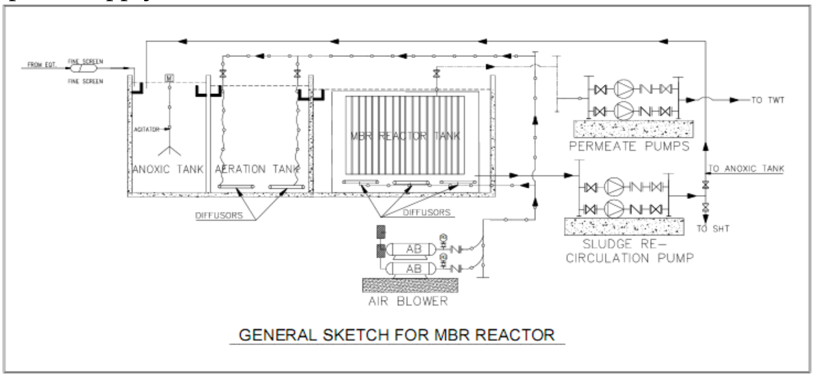

Figure-3: General sketch for MBR reactor

1.6.1 Advantages

- MBR is capable of meeting the most stringent effluent water quality standards.
- Membrane modules are back-flushable
- Requires cleaning only once in 3 to 6 months.
- Yield 60-80% less sludge than conventional system.
- Compact design- footprint 75% smaller than conventional.
- Possibility of direct and indirect water reuse.
- Highly space efficient.
- High quality effluent in a greatly simplified process.
- No secondary clarifier, virtually no effluent suspended solids, no RAS recycling.
- Maintain high MLSS
- Easily automated and instrumented to measure performance.
- It allows systems to be remotely operated and monitored, thus significantly reducing operator attendance.

- Sludge can be wasted directly from aeration tank.

1.6.2 Disadvantages

- Limited tolerance for abrasive and stringy materials, such as grit, hair and fibrous material. Accumulation of solids and sludge between membrane fibres and plates can clog/damage the membrane tube openings.
- Membrane fouling.
- Higher energy consumption to overcome trans-membrane resistance and to prevent fouling using aeration etc.
- Very high aeration requirements.
- Dual aeration system for mixing and to prevent fouling.
- Time-consuming membrane cleaning procedure.
- High capital costs for membrane system.
- Extra power requirements for vacuum on micro filter.
- Waste activated sludge is not thickened- larger volume to solids processing.
- Broken membranes result in low effluent quality.

II. COMPARISON OF TREATMENT TECHNOLOGIES

Wastewater treatment technologies can be classified under three categories based on performance parameters, land requirements, energy demand:

2.1. Category-I:

Good performance, low energy requirement, low resource requirement and associated costs, high land requirement (BOD < 30, TSS <30).

2.2 Category-II:

Good performance, high energy requirement, high resource requirement and associated costs, moderately low land requirement (BOD < 30, TSS <30).

2.3. Category-II (Improved Version):

Very good performance, very high energy requirement, very high resource requirement and associated costs, low land requirement (BOD < 20, TSS <20).

2.4. Category-II (Further Improved Version):

Very good performance, very high energy requirement, very high resource requirement and associated costs, low land requirement (BOD < 10, TSS <10).

2.5 Category-III:

Moderate performance, moderate energy requirement, moderate resource requirement and associated costs, moderate low land requirement (BOD < 30, TSS <30).

The comparison of widely used treatment technologies for hospital wastewater has been summarized below:

Table-3: Comparison of Widely Used Treatment Technologies for Hospital Wastewater

S.N.	Item Description	ASP	E.A.	SBR	FBR/FAB	SAFF	MBR
1.	Type of process	Suspended growth process	Suspended growth process	Suspended growth process	Suspended and attached growth process	Attached growth process	Suspended growth with solid-liquid separation process
2.	Typical influent characteristics for hospital wastewater	pH : 6.5 - 8.5 ; BOD_5 : 150 – 350 mg/l ; COD : 250-800 mg/l ; TSS : 150-400 mg/l, E-Coli : 10^6-10^{10} MPN/100ml					
3.	Discharge standards for hospital wastewater (Sources EPA	pH : 6.5 – 9.0 ; $BOD_5 \leq 30$ mg/l ; COD $\leq$ 250 mg/l ; TSS $\leq$ 100 mg/l; E-Coli $\leq 10^3$ MPN/100ml					

	1998)						
4.	Discharge standards for hospital wastewater (MoEF in India)	pH : 6.5 – 8.5 ; $BOD_5 \leq 10$ mg/l ; COD $\leq$ 100 mg/l ; TSS $\leq$ 10 mg/l; E-Coli $\leq 10^3$ MPN/100ml					
5.	Requirement of bio-media / diffusion membrane & their types	No	No	No	Yes & Floating Type	Yes & Fixed Type	Yes & membrane module
6.	Treatment for laundry and laboratory effluent	Yes	Yes	Yes	Yes	Yes	Yes
7.	Treatment for oil and grease from kitchen /cafeteria	Yes	Yes	Yes	Yes	Yes	Yes
8.	Pre-treatment and primary treatment for influent wastewater	Yes	Yes	Clarifier / tube settler can be eliminated	Clarifier / tube settler can be eliminated	Clarifier / tube settler can be eliminated	Clarifier / tube settler can be eliminated
9.	Secondary clarifier / tube settler tank	Yes	Yes	No	Yes	Yes	No
10.	Requirement of Equalisation tank	Yes	Yes	Can be avoided	Yes	Yes	Yes
11.	Tertiary treatment system for further polishing treated wastewater	Yes	Yes	Yes	Yes	Yes	No
12.	Expected quality of treated wastewater after tertiary treatment.	Fair	Good	Better	Much better	Much better	Excellent
13.	BOD_5 removal efficiency	90%	95%	95-97%	95-98%	95-98%	99%
14.	Remote monitoring of plant performance	No	No	Yes	No	No	Yes
15.	Sludge digestion	Less	Less	High	High	High	High
16.	Required power	Medium	Very high	Medium	Low	Very low	Very high
17	Required operator	A few staff with medium skill level	A few staff with high skill	A few staff with very high skill	A few staff with medium skill	A few staff with medium skill	A few staff with very high skill
18.	Ease of operation and maintenance problems	Easy	Easy	Difficult to control	Medium	Easy	Difficult to control
19.	Effects of climates	High	Medium	Small	Small	Small	Very small
20.	Required chemicals	Few or none	Few or none	Essential	Essential	Few or none	Essential
21.	Need for lab control	every month	every day	every hour	every day	every day	every hour

22.	Facing shock loads	No problem	Affected highly	Affected highly	Some problem	No problem	No problem
23.	Electro-mechanical Cost (Lac. /m3/d)	0.10-0.11	0.12-0.13	0.16-0.18	0.13-0.15	0.13-0.14	0.25-0.30
24.	Power cost (Kwh / ML treated)	150-200	180-225	200-250	170-200	175-225	225-275
25.	O & M cost (Rs. million / year /mld)	0.2-0.4	0.3-0.5	1.0-1.75	0.6-0.75	0.75-1.14	1.5-2.0
26.	Land requirement (m^2 / KLD)	1.5 - 2.5	2 - 3.5	0.5-0.6	0.6-0.7	0.6-0.7	0.5
27.	Application for re-use of treated sewage water.	Irrigation /horticulture	Irrigation / horticulture	Irrigation /horticulture, flushing water, cooling tower water make-up etc.	Irrigation /horticulture, flushing water, cooling tower water make-up etc.	Irrigation /horticulture, flushing water, cooling tower water make-up etc.	Irrigation /horticulture, flushing water, cooling tower water make-up etc.

III. OBJECTIVE OF FUTURE RESEARCH

- To assess the sources of wastewater in hospitals, influent characteristics, current practices adopted for treatment of wastewater.
- To compare different treatment techniques and technologies and to identify the best suitable options for treatment of hospital wastewater along with its recycling and reuse.
- To define an objective economic index derived from cost functions, including both investment and variable operating costs over the life of the treatment and recycling and reuse.
- Finally, to develop a generalized framework for recycling and reuse of wastewater in hospitals through minimization of cost of treatment and maximum reclamation of treated sewage.

IV. CONCLUSIONS

- There are large number of techniques and technologies available for treatment of wastewater. The hospital wastewater may contain various potential hazardous material require special attention , hence proper treatment and disposal is essential. It has been observed from the field visit to various hospitals that the commonly used treatment technology included ASP, EA, SBR, FBR, SAFF and MBR.
- Effluent discharge or re-use after suitable treatment protects environment and public health, government shall have to adapt integrated wastewater management approach, generates new guidelines or policies or standards (if require) and monitor and enforce existing present standards.
- Although each of these techniques/ technologies have their own advantages and disadvantages. An attempt has been made for selection of suitable treatment technology among the widely used technologies in domestic wastewater including hospital. The comparison of widely used treatment technologies will help designers, engineers, architects, economists in selection of treatment technologies in terms of their efficiency, energy, operation , performance, land requirement, cost etc.

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