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MBBR, THE MOST APPROPRIATE WASTE WATER TREATMENT TECHNOLOGY FOR PAPER EFFLUENTS

Paper Industry among other industries is also one of the most water consuming industries. Water resources are limited and it is our responsibility to adhere to good practices of safe waste water disposal in the first stage and ultimately reuse and recycle the entire waste water generated in the process.

Key words

Biofilm Carriers, Aeration Grid, Retention Sieves, Hydraulic Retention Time, Fill Fraction.

There are several technologies adopted. The most popular and time tested technology has been the activated sludge process. The recent advancement in waste water treatment has propagated mainly three technologies such as MBBR (Moving Bed Bio Film Reactor), SBR (Sequential Batch Reactor) and MBR (Membrane Bio Reactor).

Most of the plants already have an existing system which is based on activated sludge process. Over the years either the discharge limits have become stringent, or Industry on its own is contemplating reuse and recycling, or the plant expansion has bought in additional flows and load to the existing system. Most of the plant will not have enough place for expansion. In such a scenario, there has always been a need for a technology that improves the quality of the effluent, or handling larger flows or both within the existing available space.

Membrane Bio Reactor looked like a magical answer to all these problems but there were drawbacks as follows:

- The initial investment was very high
- The process involved several procedures like back washing, chemical cleaning and rejuvenation of the membranes etc. This was a maintenance nightmare.
- The membrane life was very short. In many cases the membranes choked in the first year itself. Few of the lasted five years. Again when it came for change of membranes the cost was very high, close enough to the initial investment.

The SBR also looked like a possible solution. The automation requirements were very high, the space requirement was also very large added to it were the associated maintenance.

In the above scenario, MBBR was looked as an option and fit the bill very well. My Paper will explain in detail how MBBR can be effectively used in new waste water treatment systems, how future expansion can be planned whilst initial design, retrofitting the existing system etc.

What is MBBR?

Moving Bed Bio film Reactor. Is an attached growth Process. The other attached growth process are RBC (Rotating Biological Contactor), Trickling Filter, Fixed Media Submerged Bo Filters, Granular Media Bio Filters etc.

- The process is based on the biofilm principle using the polyethylene carrier elements.
- The carrier elements, which are less dense than water, provide a large protected surface for bacteria culture.
- The MBBR provides advantages of Activated Sludge and Trickling Filter systems without the disadvantages of those systems.
- The MBBR is the most documented fixed film process with many technical publications and presentations.

Development of MBBR

- Invented in 1989 by Dr. Hallvard Ødegaard and co-workers of Norwegian University of Science and Technology (NTNU) in 1989.
- First commercialized by Kaldnes in early 1990s in Europe
- First commercialized in North America by Hydroxyl Systems Inc. (Now Headworks Bio Inc.)
- First installation of MBBR in North America in 2002 in Minnesota by Hydroxyl Systems
- More than 1,000 installations around the world by 2010s

Critical Components that go into MBBR

In India this technology has been adopted since the early 2000s. Most of the plants failed as it was sold as commodity in the form of plastic media. The failure of plants led to rejection of this technology. However worldwide this technology was very successful and gaining over other technologies. There are only a few companies who have the knowledge to design the plant adopt the right components with right MOC.

The design itself is very complicated. Unlike activated sludge process design MBBR design is not liner. In MBBR the design is iterated several times. The organisations who have developed this technology have their own proprietary software.

Media

The Media (fig 1) is a critical component. In India the recycled media had been pushed aggressively. This is because India is a price sensitive market and most of the suppliers are just responding to the market need. The media should have the following minimum characteristic

Fig 1 : Media with healthy biology from a Paper ETP

Raw Material	:	HDPE
Specific gravity	:	0.94-0.98
UV Protection	:	Needed
Virgin PE	:	Must Virgin, near virgin not acceptable
Total Surface area	:	Not significant
Protected area	:	Paramount

In addition to the above the media is generally measured in m3 and the specification generally speaks the protected surface area of the media per m3. This required specific no of pieces of media in an m3 depending on the size and shape of the media.

The life of the media is more than 20 years and never needs replacement. It could be more as the first plant in Norway is still using the same media. Also the first plant is US is also using the same media.

Sieves

The primary function of the sieves (fig 2) is to protect media from passing from one tank to another or into the over flow.

Fig 2 : A wedge wire Sieve

The sieves are generally made of SS 316 or SS 304. Wedge wire is used to stop screen form getting clogged. This also has a 20 year life cycle.

Air Grid

Air grid is generally made of SS 304 or SS 316. It is basically a wide band coarse bubble diffuser (fig 3). This does not choke and requires no maintenance and has a life of 20 years. Again this is not pipe with holes. These are engineered for greater efficiency.

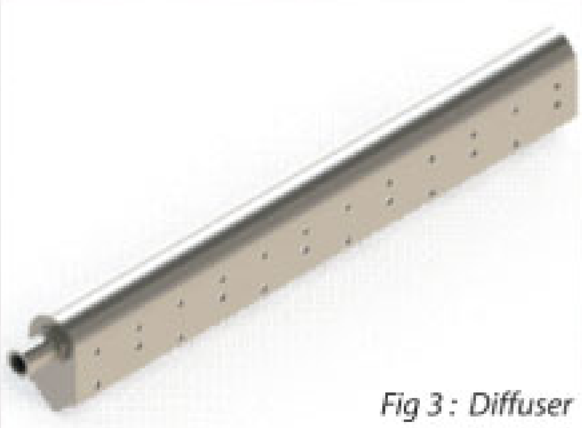

Fig 3 : Diffuser

Why MBBR

MBBR is the most versatile technology. It is more often referred to as complimentary technology rather than competitive technology. When you design a new plant, the MBBR has the following advantages:

- It occupies very less space
- It is modular and looks elegant
- Marginal expansion without any civil work possible. Can be designed for future expansions with minimal civil work
- It is single pass process and does not require recycling of active sludge
- Self-regulating and no MLSS management required hence no process adjustment required
- Resilient to shock loads and will recover automatically within few hours
- Resistant to toxic shocks
- Maintenance friendly as coarse bubble diffusers never choke and don't need replacement
- Long life cycle

If an existing ETP has no capacity in terms of flow and load and needs an upgradation / retrofitting MBBR stands tall among other technologies. It can be used in following manner:

- A single stage MBBR (also known as roughing reactor)before the existing biological process, usually after the primary system will not only knock off bulk of the load but will enable the existing system to work more efficiently by delivering more or less constant load.
- If an existing system is no good, within the available space and using the existing infrastructure, MBBR can be adopted.

Factors that affect designing a Biological plant

Any biological plant can be designed well provided all the influent parameters are available in precise nos. Following is an elaboration how parameters affect the design of a Biological system:

BOD

All the biological plants are designed on the basis of influent BOD. Since this cannot be measured online, COD and BOD readings are tabulated over a period of time and then a tentative no is correlated. This will keep varying and needs constant adjustment.

COD

This can be measured instantly and is the most popular way of assessing the performance of the ETP. However care should be taken whilst doing so. It is always better carry out tests to find out quantities of fully biodegradable COD, Slow to degrade COD and nod biodegradable COD.

COD does not play a direct role in design of the Biological plants. Usually COD is a degrading factor. The COD is always looked at as a deration of the BOD. Generally referred to as COD-BOD ratio and implications for biological wastewater. The below table gives a broad idea of the implications:

Ratio	Comment	Implication
1.5	Very Easy to Biodegrade	Reaction kinetics will be better than sewage
2	Easy to Biodegrade	Similar to sewage
3	Semi-Easy to Biodegrade	Typical limit for industrial wastewater
4	Hard to Biodegrade	Should pilot-test before offering a solution
5	Very Hard to Biodegrade	Better avoided for biological treatment

TDS

TDS is also a spoiler like the COD in designing of biological treatment plants. Separate derating factors are used for TDS. The biological plants perform well when the TDS levels are low. When the TDS reaches 1000 the reaction becomes slower. With every increase of TDS the biological reaction gets worse. TDS (especially inorganic TDS) affects biological treatment. Any TDS over 5,000 mg/l will require a pilot study. Without a pilot study, the design will lack accuracy. It is always wiser to segregate high TDS streams and treat them separately if possible.

TSS

This also play a vital role as some of the TSS will degrade and increase the load on the ETP. It is best TSS above 1000 is separated in the primary by using a primary clarifier or a DAF

FOG

If there is any oil and grease is likely to come in the influent suitable oil separation method. Any FOG level above 50 mg/l should not be let into the ETP.

Other than the above we should also look into process chemicals.

Chemicals

The following disinfection compounds should be monitored at the EQ tank.

1. Free Chlorine: should be < 2 mg/l.
2. Quaternary Ammonium compounds: should be <0.5 mg/l.

Case study

Customer	:	Inland Empire Paper
Industry	:	Industrial, Pulp and Paper
Location	:	Millwood, Washington, USA

This is a roughing reactor where MBBR is used at the initial stage to reduce the high load and at the same time absorb shock load and give s stable influent to the existing treatment system.

Background

Inland Empire Paper Company (IEP), located in Millwood, WA specializes in the production of newsprint paper using a combination of mechanical pulp and recycled newspaper pulp. IEP produces an average of 525 tons per day of newsprint and specialty paper products in 20 to 40 pound weight paper. Waste wood chips collected from local saw mills are processed to produce up to 475 tons of thermo-mechanical pulp (TMP) per day. IEP also recycles newspapers collected from around the country for the production of up to 350 tons of recycled newspaper fibre per day. The recycled newspapers undergo a deinking process and are blended with the TMP prior to the bleaching process. IEP then dilutes the bleached pulp with water to lower its consistency to approximately 1% solids for introduction to the paper machine. Water is removed via a press and dryer process to produce paper with approximately 8% final moisture content. IEP generates wastewater flows averaging 3 MGD (473 m3/hour), loaded with high strength BOD5. The wastewater is deficient in nitrogen and phosphorus, so ammonia and phosphorous are added to the system as essential nutrients for the activated sludge system. IEP also has a series of production campaigns for High Bright Paper runs that lead to higher organic loading and sludge bulking. The High Bright Paper campaigns run for a period of two days during which the wastewater treatment plant can see influent MLSS levels over 5,000 mg/L.

Challenge

The challenge for IEP was to meet the stringent effluent discharge limitations set forth by the Washington State Department of Ecology for direct discharge to the Spokane River. This was achieved in part by retrofitting an existing Stock Tank into a MBBR capable of reducing the BOD5 load by 44% prior to anexisting Orbal oxidation ditch treatment system. The goals of the project were to off-load the oxidation ditch, minimize or eliminate the growth of filament ousbacteria and provide IEP the capability for future growth in newsprint paper production. IEP also was planning for modular expansion in treatment capacity to meet more stringent effluent discharge limits and mill production increases in the future.

Design

Inland Empire Paper treated wastewater from its paper making process with an existing wastewater treatment system consisting of three major components: 462,000 gallon primary clarifier, 3-channel2.1 million gallon Orbal ditch aeration basin, and a 705,000 gallon secondary clarifier. The current wastewater treatment plant required relief from intermittent hydraulic and BOD5surges. During the summer months, the Orbal ditch experienced filamentous bacteria growth that negatively impacted settling rates in the secondary clarifier.

IEP conducted a four month pilot study using ActiveCell450 media that demonstrated the overall performance of the system along with the BOD5 loading and removal rates. The biological wastewater treatment system was designed using a combination of actual data from the pilot study and a proprietary computer modelling program.

The bioreactor was sized and designed to remove BOD5 at a nominal rate of 7.15 kg BOD5 per cubic meter of media per day, approximately a 44% reduction of influent BOD5 load. The bioreactor was sized to fit within an existing 25 foot diameter by 38.5 foot high stock tank. The tank provides approximately120,000 gallons of working capacity by operating at a nominal side wall depth (SWD) of 34.5 feet (approximately 4 feet of freeboard).

The existing stock tank was constructed of chemical and abrasion resistant tile-lined concrete furnished with a heeled bottom. This tank happened to be one of the oldest tanks at the mill site, having been constructed in 1911 (fig 4).

Fig 4 : Existing stock tank being converted to MBBR reactor

Process

Clarified wastewater from the IEP pre-clarifier is proportionally diverted to the bioreactor at a nominal flow rate of 1.58 to 2.05 MGD by means of a transfer pump and a set of control valves. Nutrients (ammonia and phosphorus) are then proportionally injected into the wastewater stream to support the biological activity of the treatment process.

The wastewater is pre-screened by a self-cleaning screening device with a ¼" perforated screen and flows under pressure to the bioreactor, entering the bottom of the tank 180° from the suction point.

The 117,000-gallon bioreactor is loaded with a 67% fill fraction of ActiveCell450 media providing 402 m2/m3 of active surface area. The neutrally buoyant ActiveCell450 media fluidized within the bioreactor provide a stable base for the growth of a diverse community of micro-organisms.

The biofilm is self-regulated by a continuous sloughing process due to the thousands of collisions per second. Excess solids exit the bioreactors via a wedge wire retaining screen as TSS with the treated effluent. This continuous sloughing action exposes the biofilm to the organic load in the wastewater and provides a self-regulated high-rate biological treatment process that is responsive to load fluctuations.

The bioreactor is provided with process air from an IEP supplied positive displacement blower. The air is diffused within the bioreactor by a 304SS coarse bubble aeration diffuser grid.

The treated wastewater is pumped from the bioreactor via an internal retention screen riser mounted vertically to minimize air entrainment and to allow maximum wastewater retention within the bioreactor. The treated effluent is directed to the aeration ditch via a transfer pump controlled with a continuous level sensing device to maintain the target liquid level in the tank.

Results

"The installation of MBBR has virtually eliminated concerns of wastewater treatment system overload and sludge bulking," said Doug Krapas of Inland Empire Paper Company. "The MBBR now allows us to operate over a wide range of process changes and endure upset conditions. The Headworks BIO group worked closely with IEP personnel through all phases of the project to assure that we had a properly functional and efficient system operation."

The ActiveCell bioreactor process was installed and commissioned in April 2007. Within three to four weeks of start-up, the system was already reaching the prescribed effluent quality targets.

The system performance has met the design criteria for the reduction in BOD5 mass, and filamentous bacteria growth in the Orbal ditch has been greatly reduced throughout all operating seasons, aided by the reduction of organic acids in the bioreactor process. Clarifier SVIs have been reduced from ~990 down to the 300s.

Wastewater Flow	:	3 MGD (473 m3/hour)
BOD Range	:	200-840 mg/L
Average BOD5	:	Design influent 600 mg/L
Effluent BOD Req.	:	250 mg/L
Average COD	:	Design influent 1,600 mg/L
Effluent COD	:	Req. 800 mg/L
pH	:	7-9.5
Temperature	:	32-40 °C (90-104 °F)