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Biological Treatment Process for Industrial Waste

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ABSTRACT: In a simplified, top-level answer to this question, a biological waste treatment system is a technology that primarily uses bacteria, some protozoa, and possibly other specialty microbes to clean water. When these microorganisms break down organic pollutants for food, they stick together, which creates a flocculation effect allowing the organic matter to settle out of the solution. This produces an easier-to-manage sludge, which is then dewatered and disposed of as solid waste. Typically broken out into three main categories, biological waste treatment can be:

1. aerobic, when microorganisms require oxygen to break down organic matter to carbon dioxide and microbial biomass
2. anaerobic, when microorganisms do not require oxygen to break down organic matter, often forming methane, carbon dioxide, and excess biomass
3. anoxic, when microorganisms use other molecules than oxygen for growth, such as for the removal of sulfate, nitrate, nitrite, selenate, and selenite

The organic contaminants these microorganisms decompose are often measured in biological oxygen demand, or BOD, which refers to the amount of dissolved oxygen needed by aerobic organisms to break down organic matter into smaller molecules. High levels of BOD indicate an elevated concentration of biodegradable material present in the waste and can be caused by the introduction of pollutants such as industrial discharges, domestic fecal wastes, or fertilizer runoff.When pollutant levels are elevated, BOD can deplete the oxygen needed by other aquatic organisms to live, leading to algal blooms, fish kills, and harmful changes to the aquatic ecosystem where the waste is discharged. Because of this, many facilities are required to treat their wastes, perhaps biologically, prior to discharge—but it's the level of organic and inorganic pollutants in relation to their discharge requirements that will dictate what specific unit operations a facility's biological waste treatment system will need and how they are sequenced and operated.In short, biological industrial waste treatment systems optimize the naturally occurring process of microbial decomposition to break down industrial waste contaminants so that they, along with other unwanted materials, can be removed. They also often replace (and are sometimes used alongside) physical and chemical treatments, which can be among the pricier treatment alternatives.

KEYWORDS: biological, treatment, waste, industrial, organic, contaminants, decompose, microbes, optimize

I.INTRODUCTION

Depending on the chemical makeup of the waste in relation to the effluent requirements, a biological waste treatment system might be composed of several different processes and numerous types of microorganisms. They will also require specific operational procedures that will vary depending on the environment needed to keep biomass growth rates optimal for the specific microbial populations. For example, it often is required to monitor and adjust aeration to maintain a consistent dissolved oxygen level to keep the system's bacteria multiplying at the appropriate rate to meet discharge requirements.[1]

In addition to dissolved oxygen, biological systems often need to be balanced for flow, load, pH, temperature, and nutrients. Balancing a combination of system factors is where the biological treatment process can become very complex. Below are examples of some common types of biological waste treatment systems, including a brief description of how they function within an industrial waste treatment regimen to give you an idea of the types of technologies and systems that might benefit your industrial facility.

Aerobic waste treatment technologies

Activated sludge was first developed in the early 1900s in England and has become the conventional biological treatment process widely used in municipal applications but can also be used in other industrial applications. Wastes from the primary treatment phase enter an aeration tank where it is aerated in the presence of suspended (freely floating) aerobic microorganisms. The organic material is broken down and consumed, forming biological solids which flocculate into larger clumps, or flocs. The suspended flocs enter a settling tank and are removed from the waste by sedimentation. Recycling of settled solids to the aeration tank controls levels of suspended solids, while excess solids are wasted as sludge. Activated sludge treatment systems typically have larger space requirements and generate large amounts of sludge, with associated disposal costs, but capital and maintenance costs are relatively low, compared to other options.[2]

Fixed-bed bioreactors, or FBBRs, developed as forced-air industrial treatment systems in the 1970s and 80s, consist of multiple-chambered tanks in which the chambers are packed tight with porous ceramic, porous foam, and/or plastic media; the waste passes through the immobilized bed of media. Of all biological treatment systems, FBBRs can hold the most contaminant-eating microbes in the smallest volume, which makes FBBRs space-saving and energy-efficient technologies ideal for treating wastes from medium to medium-high BOD feed levels down to very low effluent levels. The media is engineered to have a high enough surface area to encourage a robust biofilm formation with long solids lifespan, resulting in low sludge formation and lowest sludge disposal costs. A well-engineered fixed-bed will allow waste to flow through the system without channeling or plugging. Chambers can be aerobic and still have anoxic zones to achieve aerobic carbonaceous removal and full anoxic denitrification at the same time. More advanced biological processes can be facilitated with these systems (for example, nitrification, denitrification, deselenation, sulfide-reduction, and anammox), by having unique bacterial populations colonize the biofilm media in separate tank chambers, which can be uniquely configured to treat your facility's specific waste constituents.[3]

Moving bed bioreactors, or MBBRs, invented in the late 1980s in Norway, already has been applied in over 800 applications in more than 50 countries, with approximately half treating domestic waste and half treating industrial waste. MBBRs typically consist of aeration tanks filled with small moving polyethylene biofilm carriers held within the vessel by media retention sieves. Today the plastic biofilm carriers come from many vendors in many sizes and shapes, are typically half- to one-inch diameter cylinders or cubes and are designed to be suspended with their immobilized biofilm throughout the bioreactor by aeration or mechanical mixing.[4]

Because of the suspended moving bio-film carriers, MBBRs allow high BOD wastes to be treated in a smaller area with no plugging. MBBRs are typically followed by a secondary clarifier, but no sludge is recycled to the process; excess sludge settles, and a slurry removed by vacuum truck, or settled solids are filter pressed and disposed as a solid waste.[5]

MBBRs are often used to remove the bulk of BOD load upstream of other biological treatment processes or used in situations where effluent quality is less important; they are not used for polishing BOD to low effluent levels. They are used for treating wastes produced in food and beverage facilities, meat processing and packing plants, petrochemical facilities, and refineries.

Membrane bioreactors, or MBRs, came into common use in the 1990s once membrane modules were submerged directly in the aeration tank, and air scour was implemented to keep the membranes from fouling. MBRs are advanced biological waste treatment technologies that combine conventional suspended-growth activated sludge with membrane filtration, rather than sedimentation, to separate and recycle the suspended solids. As a result, MBRs operate with much higher mixed-liquor suspended solids (MLSS) and longer solids residence times (SRTs), producing a significantly smaller footprint with a much higher quality effluent compared to conventional activated sludge.[6]

MBRs primarily target BOD and total suspended solids (TSS). MBR system design varies depending on the nature of the waste and the treatment goals, but a typical MBR might consist of aerobic (or anaerobic) treatment tanks, an aeration system, mixers, a membrane tank, a clean-in-place system, and either a hollow fiber or flat sheet ultrafiltration membrane. As a result of its many parts and cleaning processes, MBRs are known for high capital, high operating, and high maintenance costs.

Biological trickling filters are used to remove organic contaminants from both air and waste. They work by passing air or water through a media designed to collect a biofilm on its surfaces. The biofilm may be composed of both aerobic and anaerobic bacteria which breakdown organic contaminants in water or air. Some of the media used for these systems include gravel, sand, foam, and ceramic materials. The most popular application of this technology is municipal waste treatment and air remediation to remove H2S at municipal sewer plants, but they can be used in many situations where odor control is important.[7]

Anaerobic Waste Treatment Technologies

Upflow anaerobic sludge blankets, or UASBs, useanaerobic bacteria to, as mentioned in the intro of this article,breakdown organics without the use of oxygen, resulting with a combustible methane-bearing biogas, treated effluent, and anaerobic sludge. With UASB systems, the general idea is that wastes are pumped into the base of the system, where the organics in the waste flow through a blanket of sludge before entering the upper gas-liquid-solids (GLS) separator, where collection hoods capture the biogas while allowing the suspended solids to settle and return to the lower reaction zone, while the cleaned effluent overflows out of the top of the system. The biogas (methane and carbon dioxide) is either flared or used to generate steam or electricity for use in other processes at the facility.[8]

The UASB process creates less sludge than aerobic biosystems and therefore needs to be cleaned out and emptied less than other biological treatment systems, but they require skilled operators to maintain optimal hydraulic and anaerobic conditions for UASBs to operate properly. Expanded granular sludge beds, or EGSBs, are a similar process, but EGSBs use a stronger upward force to encourage more waste-to-sludge contact.

Anaerobic digesters also useanaerobic bacteria to break down organic waste without oxygen and produce biogas, mostly for sewage treatment, and there are a variety of anaerobic digesters available. They each perform the same process in slightly different ways. Examples include covered lagoons, fixed film, suspended and submerged media, and continuous stirred tank reactors.[9]

II.DISCUSSION

Biological waste treatment is an important and integral step of waste treatment system and it treats waste coming from either residential buildings or industries etc. It is often called as Secondary Treatment process which is used to remove any contaminants that left over after primary treatment. Chemical treatment of waste water makes use of chemicals to react with pollutants present in the waste and where as biological treatment uses microorganisms to degrade waste contaminants. This treatment rely on bacteria, nematodes, algae, fungi, protozoa, rotifers to break down unstable organic wastes using normal cellular processes to stable inorganic forms. Based on the process, biological treatment of waste water methods are majorly classified into two types and are as follows:

1. Biological Aerobic Treatment (in presence of oxygen)
2. Biological Anaerobic Treatment (in absence of oxygen)[10]

1. Biological Aerobic Treatment: Aerobic waste treatment is a biological process that takes place in the presence of oxygen. It is the rapid and the most efficient biological waste treatment which remove up to 98% of organic contaminants. This process causes effective breakdown of organic pollutants and yields a cleaner water effluent than anaerobic treatment. Aerobic biological treatment processes include many processes such as activated sludge process, trickling filter, aerated lagoons and oxidation ponds etc. Activated sludge process is the most widely used process for domestic and industrial waste. Aerobic biological treatment will remain efficient and stable in all conditions.

a. Activated Sludge Process: The activated sludge process is the most widely used biological waste treatment in secondary stage of waste treatment. An activated sludge process refers to a multi-chamber reactor unit that makes use of highly concentrated microorganisms to degrade organics and remove nutrients from waste to produce a high-quality effluent. In this method, the sewage containing organic matter with the microorganisms is aerated (by a mechanical aerator) in an aeration tank. This process speeds up waste decomposition. Aeration in an activated sludge process is based on pumping air into a tank, which promotes the microbial growth in the waste. The effluent from the aeration tank containing the flocculent microbial mass, known as sludge, is separated in a settling tank, sometimes called a secondary settler or a clarifier.[11]

The activated sludge process is a very compact, low-cost and an efficient biological treatment system for sewage/waste water treatment. Conventional flow diagram for Activated Sludge Process is shown below:

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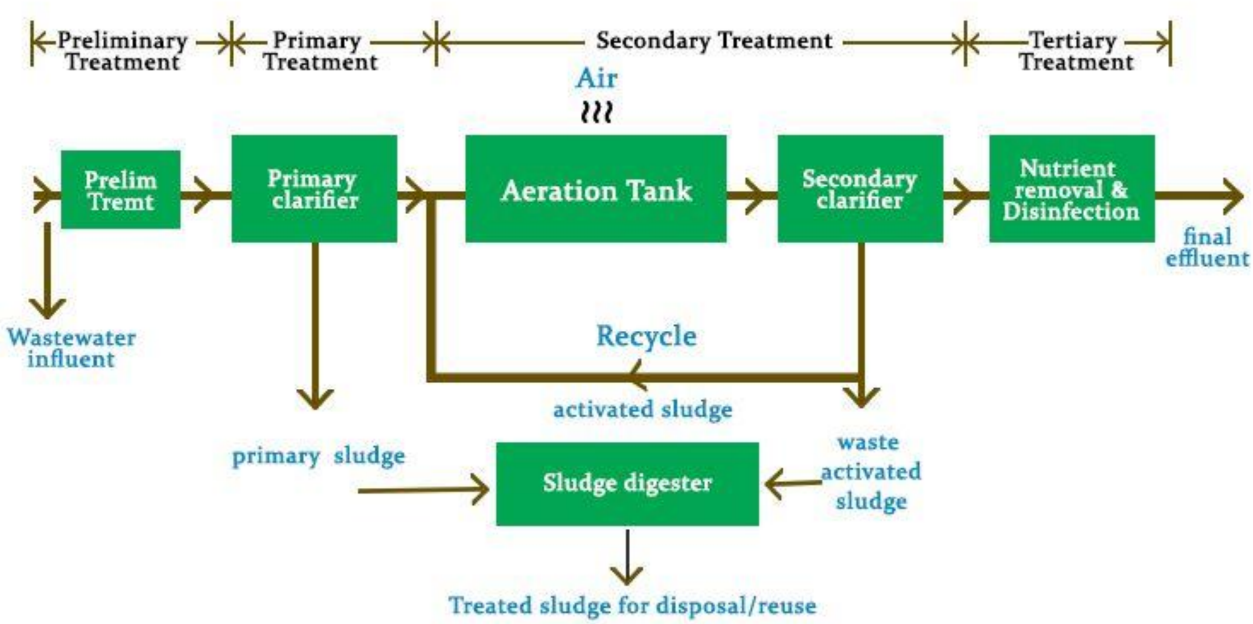

b. Trickling filters: This is the second commonly using type of aerobic treatment which is also called as percolating or sprinkling filters. These filters are commonly used to remove compounds such as ammonia from the water after primary treatment. The secondary effluent that settles will either enter a digest

c. Aerated Lagoons: It is one of the aerobic biological waste or waste treatment process. An aerated lagoon is a treatment pond that is provided with mechanical aeration that introduces oxygen into the pond in order to promote the biological oxidation of the waste. The effluent of aerated ponds may be reused or used for recharge, but settled sludge requires a further treatment.[12]

d. Oxidation Pond: The ponds involve an interaction between bacteria, algae and other organisms which feed on the organic matter received from primary effluent. These ponds are also productive, because it generates effluent that can be used for other applications. Overall the process is slow and requires large areas of land. Typically oxidation ponds are used in areas with small populations where land is readily available.

2. Biological Anaerobic Treatment: This treatment process is effectively utilized to treat high strength waste water and it employs organisms that function in the absence of oxygen and it will typically treat high-strength waste water to a level that will permit discharge to a municipal sewer system. Here, the amount of sludge produced is very small when we compared to aerobic treatment. Anaerobic treatment is a slow process and it occurs in many different stages. Anaerobic digestion is biological process which is used in waste treatment plants for sludge degradation and stabilization. Once the process is completed, the waste can undergo many additional treatments. This process is accepted because it is able to stabilize the water with little biomass production. Biogas is produced as the bacteria feed off the biodegradable material in the anaerobic process. Overall, the process converts about 40% to 60% of the organic solids to methane (CH_4) and carbon dioxide (CO_2).[13]

Finally, the type of biological treatments selected — whether aerobic or anaerobic — depends on a many range of factors.

III.RESULTS

Discharge permits are focusing more on Biological Oxygen Demand (BOD) and nutrient removal than metal removal. With this trend, we can no longer focus on just meeting the metal removal requirements. We must now focus on how to continue to meet the metal removal requirements while also meeting new BOD and nutrient removal requirements. This cannot always be done via physical/chemical means.[14]

Enter the world of bacteria. These amazing creatures live to eat what we no longer find desirable in water. Special blends of bacteria can consume enough phosphorus to make it nondetectable in testing. While they do this, they also consume nitrogen and BOD. What types of bacteria can do this? What are their needs to stay healthy and alive long enough to do their job for us? How can an industrial manufacturer, whose water is often deadly to bacteria, utilize them in small tight spaces? We will explore these questions, see photos of healthy bacteria, and discuss how to utilize them for your needs in detail.

Terminology

In order to properly discuss the ins and outs of biochemical waste treatment, it is important to review the nomenclature involved.

BOD5 measures the quantity of biodegradable organic matter contained in water. This biodegradable organic matter is evaluated using the oxygen consumed by the microorganisms involved in natural purification mechanisms.

Chemical oxygen demand, or COD, is one of the parameters of water quality. It represents the quantity of oxygen needed to oxidize all of the organic matter contained in water.

TKN (Total Kjeldahl Nitrogen) is the total concentration of organic nitrogen and ammonia.

The TP, or total phosphorus, is a sum parameter that shows the organic and inorganic phosphorus compounds in water.[15]

Total Suspended Solids (TSS) is a measurement of the total solids in a water or waste sample that are retained by filtration.

Categorical pretreatment standards [paraphrased from 40 CFR 403.6] are standards specifying the quantity, concentration or pollutant properties of pollutants that may be discharged to publicly-owned treatment works (POTWs). EPA promulgates pretreatment standards for specific industry categories in accordance with CWA section 307. These standards are codified in 40 CFR chapter I, subchapter N, Parts 405–471.[16]

Local limits [40 CFR 403.5(c)] are specific discharge limits developed and enforced by POTWs on industrial or commercial facilities (IUs) to implement the general and specific discharge prohibitions listed in 40 CFR 403.5(a)(1) and (b).

These are important because local authorities are really tightening the belt for industrial users to try to offset some of these pollutants. They are allotting surcharges to the tune of tens of thousands of dollars a month in some cases where the industry cannot meet the new limits that have been set in places.

Surcharges are additional fees charged to industrial users above and beyond the normal discharge fees. These fees are collected to help offset the cost of the treatment of the waste sent to the city's treatment plant. The problem with this is that, if an industrial user is sending already treated water to the city, then the city is charging the industrial user to treat the same waste a second time. The industrial user is paying the city to do what their own treatment plant is failing to do while still paying for their treatment plant to run. This is not LEAN Waste Management.[17]

Fines are assessed when an industrial user sends noncompliant waste to the city treatment plant. These are usually seen when the waste damages the treatment plant and are set. When big enough, jail time can accompany fines.

The current situation

Traditionally, physical and chemical treatments have worked for industrial users - so far. These processes have allowed metal finishers to remove heavy metals such as chromium, nickel, zinc, lead, cadmium, etc., successfully. These systems have played a huge part in allowing our environment to move past the early days of industrial revolution where rivers were on fire, smells were horrendous, and people could not safely drink the water. These systems will continue to play a vital role in all metal finishing companies around the world.

As focus is moving away from metals and inorganic contaminants, we have to shift our way of thinking on how industrial waste treatment plants look and work. We will, for the foreseeable future anyway, still need those physical/chemical systems for pretreatment, but they will need to have a secondary treatment as well.[18]

Treatment technologies

Biological waste treatment comes in many shapes and sizes, including:

- Activated sludge plant (ASP)
- Rotating disc system.
- Submerged aerated filter (SAF)
- Suspended Media Filters (SMF)
- Sequencing batch reactor (SBR)
- Non-electric filter.
- Trickling filter

There are all types of waste treatment plants out there. When we think of them as biological treatment plants, we see in our mind these huge plants that take up hundreds of acres and need a lot of operators and attention. We think of the cities we discharge to and how huge they are in comparison to our industrial plants. We think bacteria are picky creatures and easy to kill. But, some of them can be fitted for industrial usage.

Trickling filters: One example is an industrial trickling filter,[1,2] . It involves a treatment process in which waste trickling over media enables the formation of slimes or biomass which contain organisms that feed upon and remove wastes from the water being treated (Office of Water Programs, CSU, Sacramento).[19]

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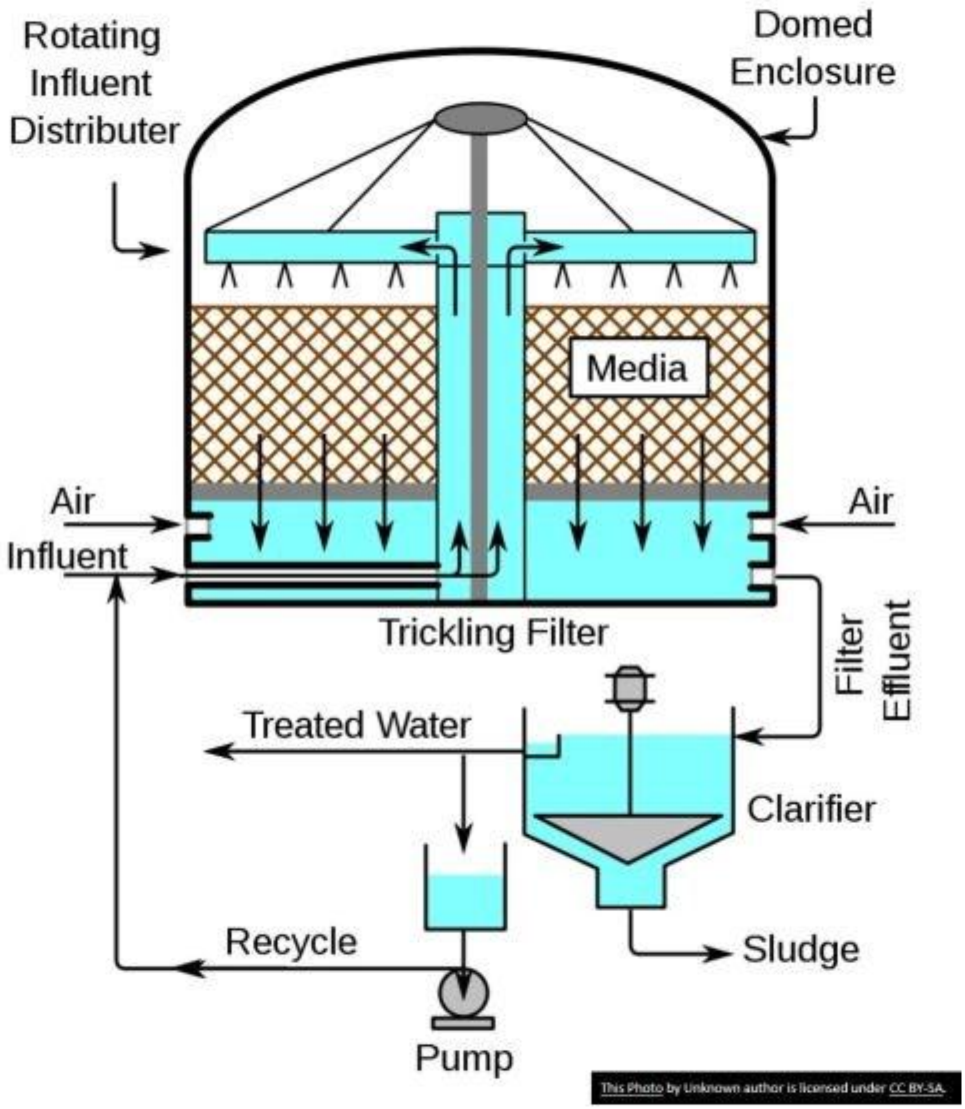

Figure 1 - Schematic diagram of a trickling filter.

Trickling filters are specified by loading rate (i.e., capacity). Low rate filters are used for loading less than 25 lb. BOD5 per 1000 ft^3/day with a BOD removal efficiency of 80-90%. Intermediate trickling filters handle up to 400 lb. BOD5 per 1000 ft3/day with a BOD removal efficiency of 50-70%. High rate filters handle a maximum organic loading of 100 lb. BOD5 per 1000 ft^3/day with a BOD removal efficiency of 65-85%. Roughing filters allow a significant amount of soluble BOD to bleed through filter loads between 100 and 300 lb.

Trickling filters do come with problems, including odors, ponding, filter flies and icing. Overall however, they provide the lowest cost for maintenance and operation of any bio system.[20]

Rotating biological contactor: A rotating biological contactor (RBC) is a biological treatment device in which a population of microorganisms is alternately exposed to waste and then air (oxygen) to promote growth of the organisms as they oxidize the waste solids (Fig. 2)(Office of Water Programs, CSU, Sacramento).

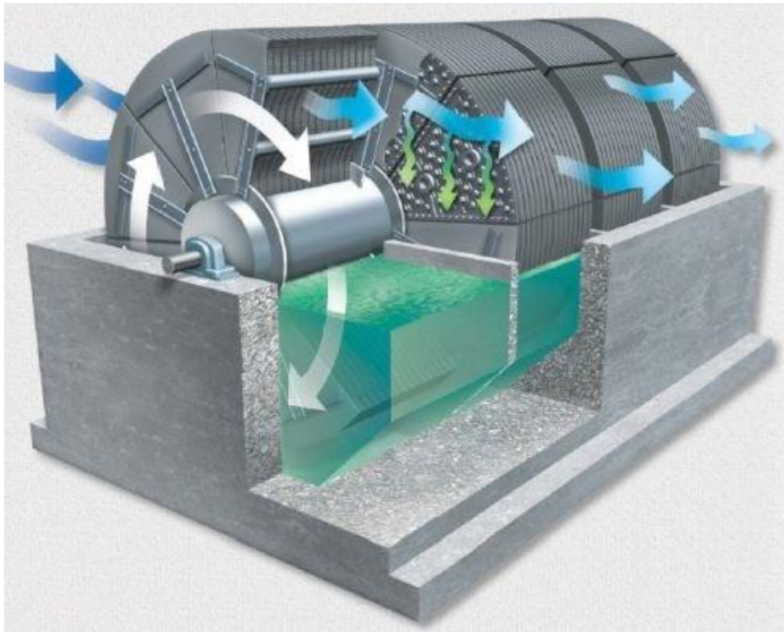

Figure 2 - Rotating biological contactor (Figure courtesy of Walker Process Equipment).

Performance data for a modified rotating biological contactor fitted with perforated baffles is shown in Table 1.[3] Efficiency values for both BOD and COD are given versus detention time and rotational speed.

Table 1 - BOD / COD removal rates for a rotating biological contactor.

Detention time (hr)	BOD Removal (%)	COD Removal (%)
18	58.8	68.1
21	62.3	64.2
24	67.0	69.0
Rotation speed (rpm)		
3	59.19	58.90
5	55.85	54.84
7	51.59	52.61

Membrane bioreactor: A membrane bioreactor (MBR) (Fig. 3) is generally a term used to define waste treatment processes where a perm-selective membrane, e.g., microfiltration or ultrafiltration, is integrated with a biological process - specifically a suspended growth bioreactor.[4] Performance data for an MBR in terms of the composition of the influent and effluent is given in Table 2 for a case study at the Guggisberg Cheese plant in Millersburg, Ohio.[5]

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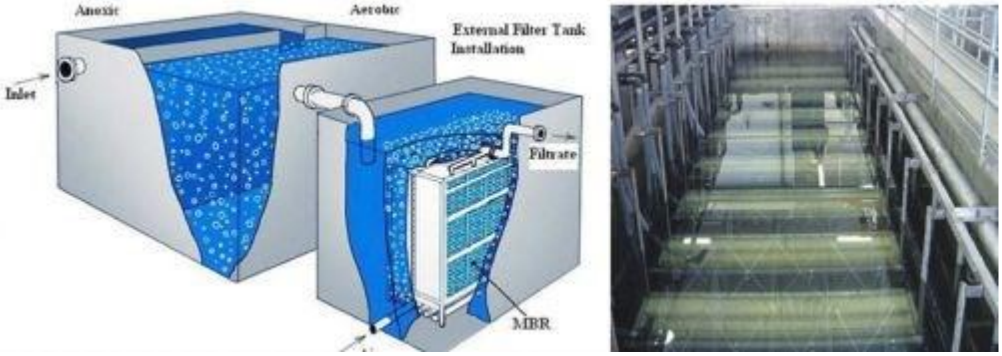

Figure 3 - Membrane bioreactor.

Table 2 - Membrane bioreactor data from a case study (Guggisberg Cheese, Millersburg, Ohio).[5]

Parameter	Influent (Commingled)	Effluent
Wastewater flow	300,000 gal/day	-----
BOD	1,133 mg/L	< 3.74 mg/L
TSS	346 mg/L	< 6.9 mg/L
TKN	18.6 mg/L	N.A.
Ammonia	N.A.	< 1 mg/L
Total phosphorus	25 mg/L	< 1 mg/L

For fixed growth systems, as discussed here, there must be a place for the biomass to grow. There are as many media types as there are system sizes. Figure 4 shows just a few of the available varieties. Depending on what you want and need to remove, your design engineer will be able to recommend the right media aid for your bio system.[15]

Figure 4 - Examples of media available for biological waste treatment.

Bacteria: The types of bacteria typically involved in biological waste treatment are shown in Fig. 5.

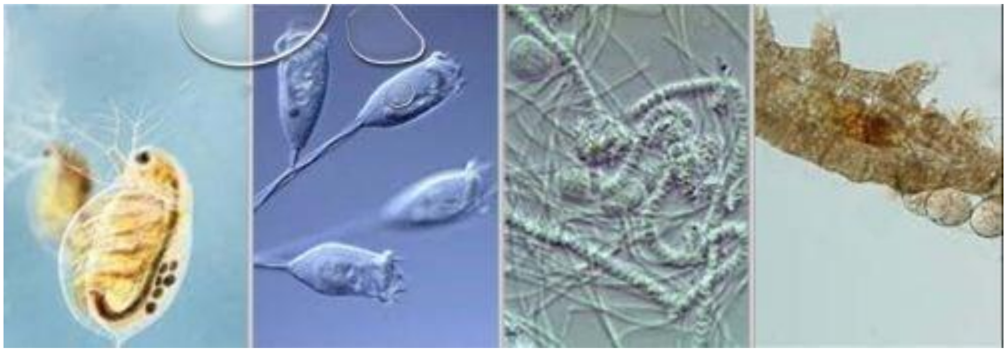

Figure 5 - Types of bacteria typically involved in biological waste treatment: (L-R) daphnia; stalked ciliates; filamentous; tardigrades.

Daphnia, or water fleas, swim in a jerky, hopping motion like a flea. A carapace (shell) covers most of its body. The carapace is hinged on one side. The other side is open to allow the water flea's legs to move through the water to collect food and to swim.

Stalked ciliates can be seen in single organism form or can grow in colonies. Each "head" in a colony of stalked ciliates is considered one organism.

The presence of some filamentous bacteria is beneficial in floc formation to a biomass. The filaments connect to each other and form a mesh that is crucial for floc formation. Filamentous bacteria serve as a base of the structure on which other bacteria can attach and form flocs which are important in flocculation and settling.[17]

Tardigrades, often called water bears or moss piglets, are near-microscopic animals with long, plump bodies and scrunched-up heads. They have eight legs, and hands with four to eight claws on each. While strangely cute, these tiny animals are almost indestructible and can even survive in outer space.[6]

Industrial performance in real time

As shown on **Fig. 6,** under a microscope, a healthy mix of bacteria from an industrial trickling filter can be seen in the influent (L) and effluent (R). Between these two photos, TKN is reduced from 9.57 to less than 1 mg/L. Phosphorus is reduced from 12.7 to 0.154 mg/L, while the COD influent of 121 mg/L is not detected in the effluent.

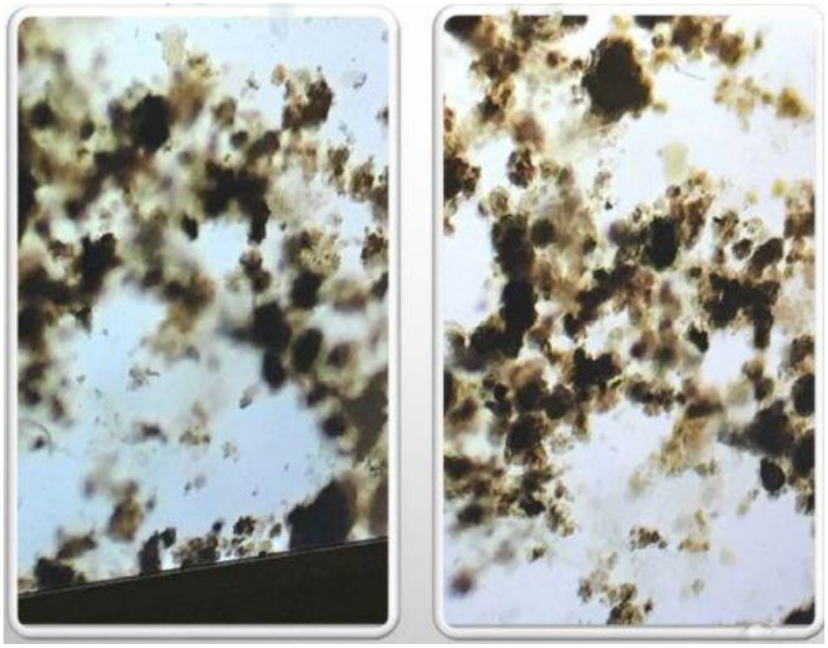

Figure 6 - Industrial biological treatment in real time.

Conclusions

Chemical, pharmaceutical and related industries produce large amounts of waste in their production and cleaning processes. The waste characteristics are often diverse, and may include minimally biodegradable or toxic substances, or both. To protect the environment, these wastes typically must be treated to minimize pollutant concentrations before discharging to the environment, or to municipal waste-treatment plants for further treatment. Compared to chemical and physical treatment methods, biological treatment processes are very economical and efficient options when the wastes contain biodegradable pollutants.[20]

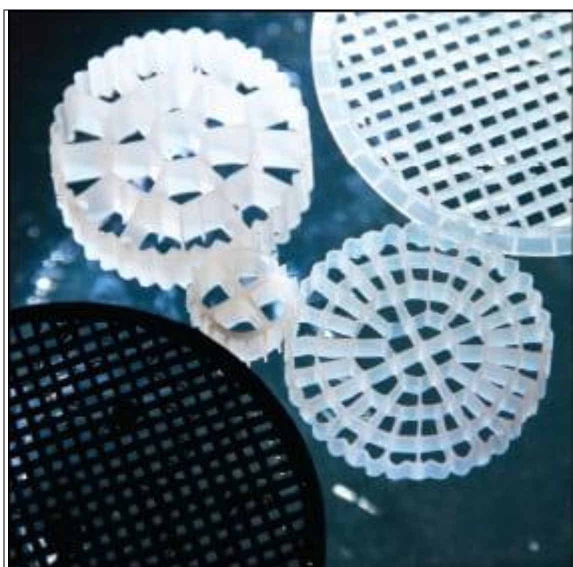

Figure 7. Assorted media is used to carry biomass in an MBBR system

Figure 8. Aeration grids in the bottom of an MBBR reactor supply the oxygen needed for biomass growth

Figure 9. Biological growth on the carrier forms a thin biofilm on the media in an MBBR system

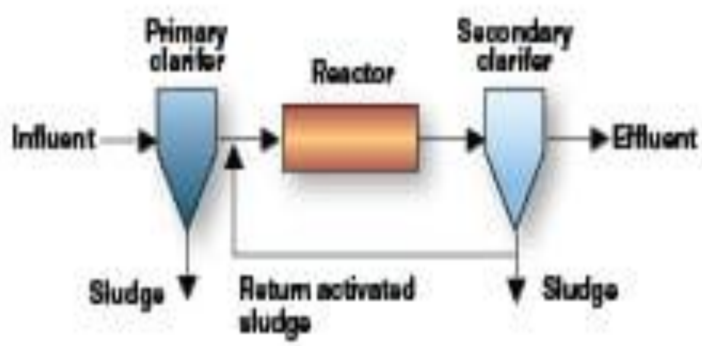

Figure 10. Activated sludge is a conventional biological treatment process

Biological waste-treatment processes are widely adapted to remove soluble, colloidal and suspended organic substances. Biological treatment is also used for nitrogen and phosphorus removal. The two categories of biological treatment are suspended-growth and attached-growth processes. In the suspended-growth category, the most widely used process is activated sludge. An attached-growth process that can provide the same treatment capacity as activated sludge in a smaller footprint (60% less) is the moving bed biofilm reactor (MBBR). The first MBBR was installed in Steinsholt, Norway in

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1989. Today, as regulatory restrictions continue to become more stringent, MBBR technology is becoming increasingly popular due to its application flexibility.An MBBR system uses inert, plastic media in various configurations to provide high surface area to carry the biomass that treats the waste. Aeration grids installed at the bottom of the tank provide the oxygen needed for the bacteria to thrive and to keep the carriers in suspension within the tank .The movement of the carriers in the tank maintains a thin biofilm on the media .Using a specific example from pharmaceutical company AstraZeneca, this article explains how a biological waste-treatment process was developed for a challenging situation where the waste contained toxic constituents.[18]

Basic process comparison

Activated sludge is a conventional biological waste-treatment process. It has been used extensively in its original form, as well as with many modifications. There are three basic components in the activated sludge process: (1) a biological reactor in which the microorganisms responsible for treatment are kept in suspension and aerated; (2) a clarifier for liquid-solids separation; and (3) a recycle system for returning solids removed from the liquid-solids separation unit back to the reactor.

Activated sludge is a widely used biological treatment process. It produces a good-quality effluent, but is more sensitive than an MBBR to shock loads and toxic matter. The system is associated with biomass instability issues, such as sludge bulking. Skilled operators are required to check that the returned sludge remains active, and to adjust the operating conditions to react to the changes immediately.[19]

In an MBBR system, biofilm is attached and grown onto the surface of plastic media. The media and biofilm are retained in the reactor by sieves. Only a small portion of sloughed-off biofilm exits the MBBR tank together with the liquid. As a result, there is no need for sludge recycling in an MBBR system. Figure 5 shows the configuration of a basic MBBR system.

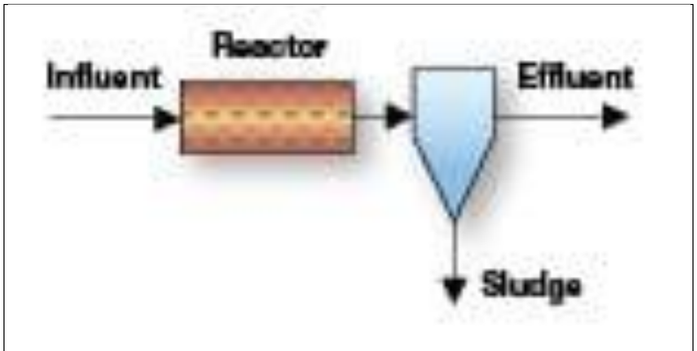

Figure 11. An MBBR process requires no sludge recycling

Compared to activated sludge systems, MBBR has more sludge in the reactor and a higher sludge age. The higher sludge age makes it possible for the biomass in the MBBR to adapt to complex molecules and ultimately to degrade them. MBBR is also more tolerant to shocks of both hydraulic and organic loads, making it a better choice for waste with varying flow and characteristics. With the larger amount of sludge in the system, the MBBR can be designed at a higher loading rate, thus reducing the footprint as compared to activated sludge. Multistage MBBR processes can use different biomass in the subsequent stages to target specific difficult-to-degrade pollutants in each stage. Because a sludge recycle system is not needed, the operation of an MBBR is much simpler and robust than an activated-sludge system.[20]

Choosing the best approach

Every biological process has its advantages and disadvantages. In practice, the selection of the most appropriate process needs to consider both technical and economical factors. The decision is made based on a balance between these two

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aspects. Technically, the appropriate process is determined according to the waste characteristics, discharge requirements, available plant space and allocated budget.

The diversity of process waters within the chemical and pharmaceutical industries is enormous. Typical characteristics for wastes from the chemical and pharmaceutical industries include:

• High organic content, of which some components (typically solvents such as alcohols or glycols) are easily degradable

• Variations in flow and influent waste characteristics caused by campaign production and varying compositions

• The presence of toxic and persistent substances[16]

Because of the diversity of wastes generated by these industries, each application usually calls for a tailor-made treatment solution. A bench-scale or pilot-scale test is often necessary to verify treatment efficacy and establish the optimal operating parameters. If toxic or persistent substances are present, the biological treatment process may require lower loading rates or multistage steps to achieve the desired treatment results.[20]

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