

Biological Wastewater Treatment for Finishing Applications

With tightening limits on nutrients and Biological Oxygen Demand (BOD), is a small-scale biological system right for your industrial facility?

We will explore the ins and outs of biological wastewater treatment and how it fits into the industrial world around us. We will look at system sizes and requirements, bacteria and their capabilities, and how to successfully treat them via physical/chemical means while still using bacteria as a final polish for your needs.

Introduction

Discharge permits focus on biological oxygen demand (BOD) and nutrient removal rather than metal removal. With this trend, we can no longer just meet the metal removal requirements. We must now continue to meet the metal removal requirements while meeting new BOD and nutrient removal requirements. This cannot always be done via physical/chemical means.

Enter the world of bacteria. These fantastic creatures live to eat what we no longer find desirable in water. Unique 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 use them for your needs in detail.

Terminology

It is essential to review the nomenclature involved to properly discuss the ins and outs of biochemical wastewater treatment.

- **BOD5** measures the quantity of biodegradable organic matter contained in water. This biodegradable organic matter is evaluated using the oxygen the microorganisms consume in natural purification mechanisms.
- **Chemical oxygen demand, or COD**, is a water quality parameter. It represents the quantity of oxygen needed to oxidize all the organic matter 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.
- **Total Suspended Solids (TSS)** measures the total solids in a water or wastewater sample retained by filtration.
- **Categorical pretreatment standards** [paraphrased from 40 CFR 403.6] specify 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 following CWA section 307. These standards are codified in 40 CFR chapter I, subchapter N, Parts 405–471.

- **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 tightening the belt for industrial users to offset some of these pollutants. In some cases, they are allotting surcharges of tens of thousands of dollars a month when the industry cannot meet the new limits that have been set in place.

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 wastewater 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 wastewater 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 Wastewater Management.

Fines are assessed when an industrial user sends non-compliant wastewater to the city treatment plant. These are usually seen when the wastewater damages the treatment plant and is set. When the fines are big enough, jail time can accompany them.

The Current Situation

Physical and chemical treatments have traditionally worked for industrial users. These processes have allowed metal finishers to successfully remove heavy metals such as chromium, nickel, zinc, lead, cadmium, etc. These systems played a huge part in allowing our environment to move past the early days of the Industrial Revolution when 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 worldwide.

As the focus moves away from metals and inorganic contaminants, we must shift our way of thinking about how industrial wastewater treatment plants look and work. We will still need those physical/chemical systems for pretreatment for the foreseeable future anyway, but they will also need to have a secondary treatment.

Treatment Technologies

Biological wastewater 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 wastewater treatment plants out there. When we think of them as biological treatment plants, we see 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 compared to our industrial plants.

We think bacteria are picky creatures and easy to kill. However, some of them can be used for industrial purposes.

One example is an industrial trickling filter,^{1,2} shown in Fig. 1. It involves a treatment process in which wastewater trickling over media enables the formation of slimes or biomass, which contain organisms that feed upon and remove waste from the treated water (Office of Water Programs, CSU, Sacramento).

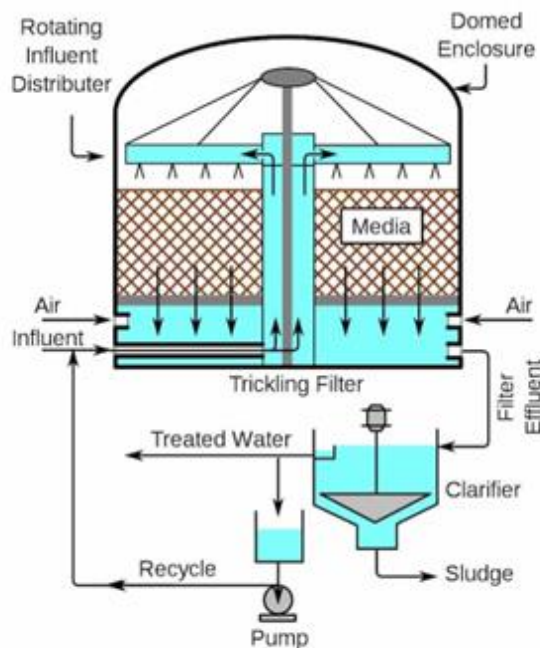


Figure 1 - Schematic diagram of a trickling filter.

Trickling filters are specified by loading rate (i.e., capacity). Low-rate filters are used for loading less than 25 lb. BOD₅ per 1000 ft³/day with a BOD removal efficiency of 80%-90%. Intermediate trickling filters handle up to 400 lb. BOD₅ per 1,000 ft³/day with a BOD removal efficiency of 50%-70%. High-rate filters handle a maximum organic loading of 100 lb. BOD₅ per 1,000 ft³/day with a BOD removal efficiency of 65%-85%. Roughing filters allow significant soluble BOD to bleed through filter loads between 100 and 300 lb.

Trickling filters come with problems, including odors, ponding, filter flies, and icing. Overall, however, they provide the lowest cost for the maintenance and operation of any biosystem.

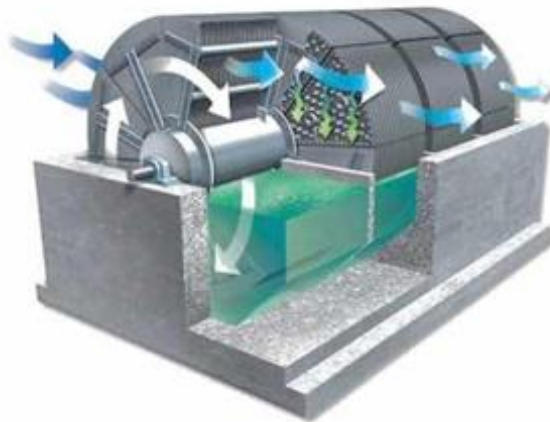


Figure 2 - Rotating biological contractor.
 (Figure courtesy of Walker Process Equipment).

Rotating Biological Contactor

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

Table 1.3 shows performance data for a modified rotating biological contactor fitted with perforated baffles. Efficiency values for both BOD and COD are given versus detention time and rotational speed.

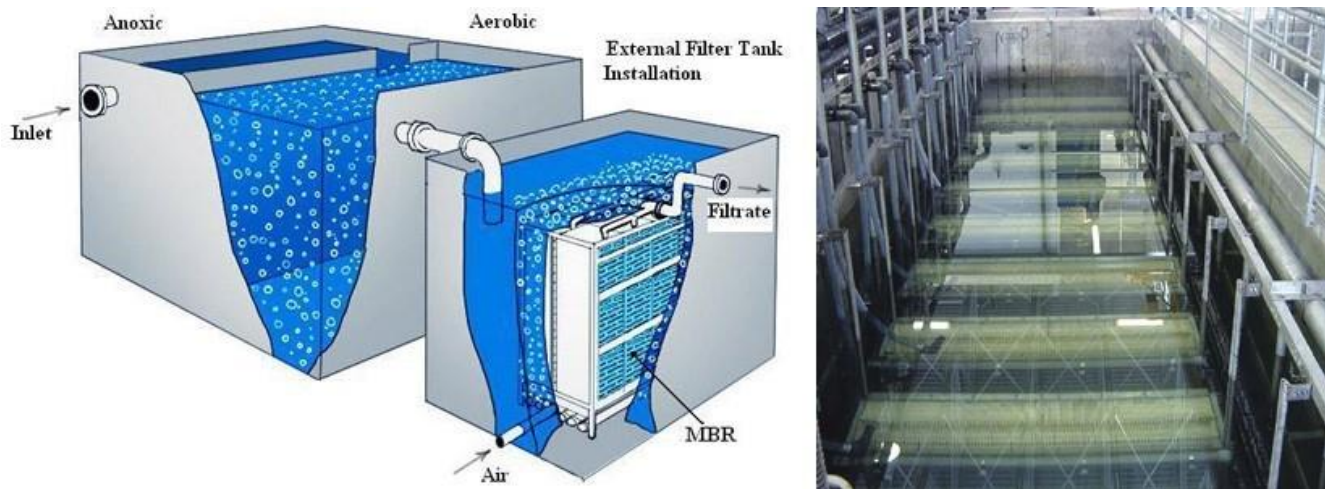
Table 1 - BOD / COD removal rates for a rotating biological contactor.

Detention time (hr)	BOD Removal (%)	COD Removal (%)
18	58.8	68.1
21	62.3	64.2
24	67	69

Rotation speed (rpm)	BOD Removal (%)	COD Removal (%)
3	59.19	58.90
5	55.85	54.84
7	51.59	52.61

A membrane bioreactor (MBR) (Fig. 3) is generally used to define wastewater treatment processes where a perm-selective membrane, e.g., microfiltration or ultrafiltration, is integrated with a biological process - specifically a suspended growth bioreactor.⁴

Figure 3 – Membrane bioreactor.



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

Table 2 - Membrane bioreactor data from a case study.

Parameter	Influent (Commingled)	Effluent
Wastewater flow	300000 gal/day	—
BOD	1133 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, the biomass must have a place 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 can recommend the right media aid for your biosystem.



Figure 4 – Examples of media available for biological wastewater treatment.

Bacteria

The types of bacteria typically involved in biological wastewater treatment are shown in Fig. 5.

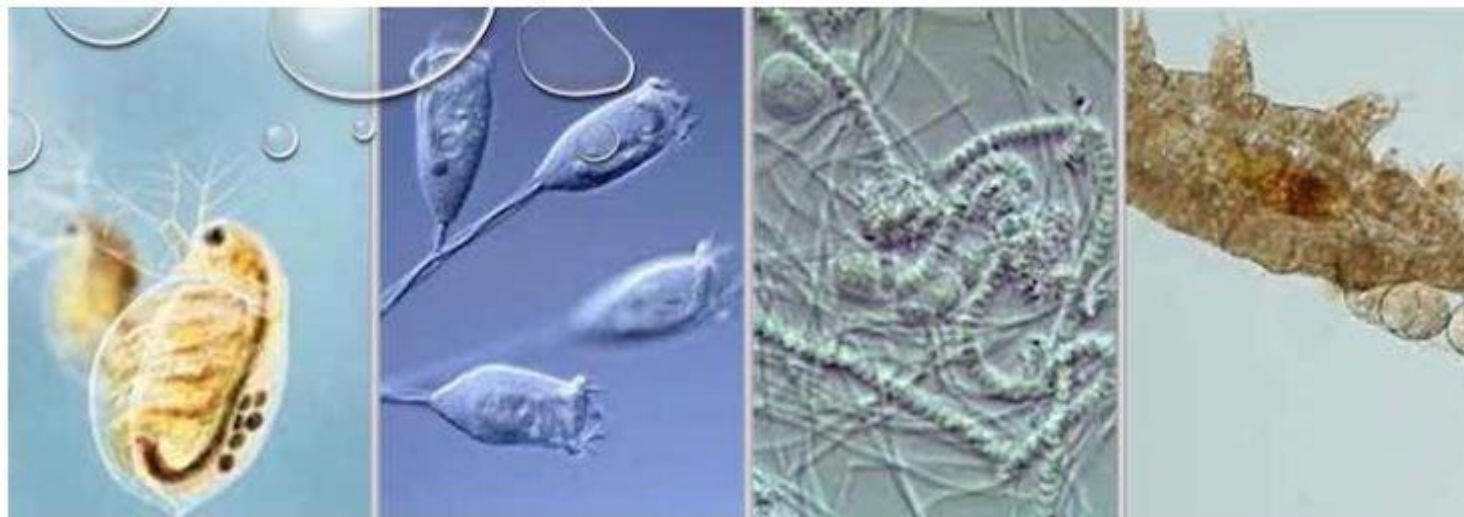


Figure 5 – Types of bacteria typically involved in biological wastewater treatment:
 (L-R) daphnia; stalked ciliates; filamentous; tardigrades.

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, and the other side is open to allow the water flea’s legs to move through the water to collect food and swim.

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

Some filamentous bacteria are beneficial in floc formation to a biomass. The filaments connect and form a mesh that is crucial for floc formation. Filamentous bacteria are a base of the structure on which other bacteria can attach and form flocs, which are important in flocculation and settling.

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 survive in outer space.⁶



Figure 6 - Industrial biological treatment in real time: (L) influent and (R) effluent.

Industrial Performance in Real Time

As shown in Fig. 6, a healthy mix of bacteria from an industrial trickling filter can be seen in the influent (L) and effluent (R) under a microscope. TKN is reduced from 9.57 to less than 1 mg/L between these two photos. 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.

References

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