

BIOLOGICAL AND CHEMICAL OXYGEN DEMAND FOR DIFFERENT FOOD PLANT WASTE

Water is one of nature's most precious resources. Groundwater is essential in sustaining plant and animal life and as a raw material for many industries. Wastewater is water that has been contaminated from human activity, environmental, or industrial processes and must be treated for reuse or safe disposal.

Usually determined alongside chemical oxygen demand (COD) in wastewater treatment, BOD is an important index that every industrial and municipal authority in the country should be aware of.

WHAT IS BIOLOGICAL OXYGEN DEMAND IN WASTEWATER TREATMENT?

Biochemical oxygen demand or biological oxygen demand (BOD) is a measure of the amount of Dissolved Oxygen (DO) required by aerobic microorganisms to decompose organic matter present in a sample of water at a certain temperature over a studied period. BOD value is usually expressed in milligrams of oxygen per liter of water (mg/L).

WHAT IS DISSOLVED OXYGEN?

Dissolved Oxygen is the amount of gaseous oxygen dissolved in a sample of water. O_2 can be absorbed directly from the atmosphere or indirectly from the by-product of photosynthesis in surrounding plants.

THE SIGNIFICANCE OF BIOLOGICAL OXYGEN DEMAND

Both aquatic life and microorganisms require oxygen to survive. Microbes utilize dissolved O_2 in water to break down complex organic compounds present in the water such as sugars, cellulose, and other convertible synthetic substances. Marine animals such as fish use dissolved oxygen for respiration.

However, the balance of DO consumption is quite delicate. When a large number of organic compounds are present in water, microbial activity will proliferate, putting a strain on the aquatic ecosystem. Critical DO reduction will ultimately harm marine life.

THE SIGNIFICANCE OF BOD IN WASTEWATER TREATMENT



Regulations concerning permissible BOD levels for wastewater disposal in industries and municipalities vary from state to state. BOD is listed as a conventional pollutant under the U.S. Clean Water Act. Typical maximum values range from 10 mg/L for direct environmental disposal and 300 mg/L for disposal to sewer systems.

Knowing BOD value helps municipal authorities determine their biological water quality and industries to assess the impact effluent disposal will have on the immediate environment.

APPLICATIONS OF BIOLOGICAL OXYGEN DEMAND IN WASTEWATER TREATMENT

Wastewater treatment plants use BOD value as an index to ascertain the overall degree of organic pollution in a water source. A BOD test is typically carried out over a standard 5-day incubation period at 20°C (68°F) for the most accurate results.

Generally, a higher BOD value indicates a higher level of water pollution, while a lower BOD value indicates less polluted, or cleaner water.

BENEFITS OF BOD REMOVAL WASTEWATER TREATMENT

Municipalities can use a BOD test to detect water contamination in their public supply to ensure that it is safe for human consumption. Industries need to know their BOD value to determine when treated wastewater is safe for reuse or disposal.

How to Reduce BOD in Industrial Wastewater

Several techniques are used for BOD removal in wastewater prior to reuse or safe disposal. Three common BOD reduction methods for wastewater treatment are:

- Wastewater clarification
- Wastewater separation (Coagulation & Flocculation)
- Anaerobic microbial decomposition

Wastewater clarification and separation BOD reduction methods are part of the primary phase of wastewater treatment while anaerobic microbial decomposition is part of the second phase of treatment.

WASTEWATER CLARIFICATION



Wastewater clarification removes organic solids (primary sludge) from the water by utilizing the force of gravity – in other words, the heavier particles settle to the bottom and are removed first. Wastewater clarification is often followed by a chemical separation process.

WASTEWATER SEPARATION (COAGULATION AND FLOCCULATION)

Wastewater separation removes any colloidal solids suspended in wastewater by coagulation and flocculation.

In coagulation, a non-toxic agglomerating agent such as Ferric Chloride (FeCl_3) or alum is added to the wastewater causing the suspended particles to come together to form *clumps* which can easily be removed from the water by filtration.

Flocculation uses a chemical polymer (flocculating agent) to precipitate organic particles out of the water by coalescing to form larger particles or *flocs*. These larger particles can then be deposited into a sedimentation tank for further treatment prior to disposal.

Removal of organic matter from wastewater using coagulants and flocculants eliminates the 'food' necessary for microbes to thrive, thus reducing the competition for dissolved oxygen with marine life.

ANAEROBIC MICROBIAL DECOMPOSITION

Anaerobic microbial decomposition introduces microorganisms or bacteria cultures into wastewater in the absence of air to break down the organic particles present. The product of an anaerobic digestion process is the generation of biogas.

Anaerobic decomposition is a highly beneficial method because the biofuel generated from the process can be utilized as an alternative energy source for power, heating, and drying applications.

PRETREATMENT OF WASTE BY TRIKLING FILTERS,OXIDATION DITCHES,ACTIVATED SLUDGE PROCESS,ROTATING BIOLOGICAL CONTRACTORS

The objective of secondary treatment is the further treatment of the effluent from primary treatment to remove the residual organics and suspended solids. In most cases, secondary treatment follows primary treatment and involves the removal of biodegradable dissolved and colloidal organic matter using aerobic biological treatment processes. Aerobic biological treatment (see Box) is performed in the presence of oxygen by aerobic microorganisms (principally bacteria) that metabolize the organic matter in the wastewater, thereby producing more microorganisms and inorganic end-products (principally CO_2 , NH_3 , and H_2O). Several aerobic biological processes are used for secondary treatment differing primarily in the manner in which oxygen is supplied to the microorganisms and in the rate at which organisms metabolize the organic matter.

High-rate biological processes are characterized by relatively small reactor volumes and high concentrations of microorganisms compared with low rate processes. Consequently, the growth rate of new organisms is much greater in high-rate systems because of the well controlled environment. The microorganisms must be separated from the treated wastewater by sedimentation to produce clarified secondary effluent. The sedimentation tanks used in secondary treatment, often referred to as secondary clarifiers, operate in the same basic manner as the primary clarifiers described previously. The biological solids removed during secondary sedimentation, called secondary or biological sludge, are normally combined with primary sludge for sludge processing.

Common high-rate processes include the activated sludge processes, trickling filters or biofilters, oxidation ditches, and rotating biological contactors (RBC). A combination of two of these processes in series (e.g., biofilter followed by activated sludge) is sometimes used to treat municipal wastewater containing a high concentration of organic material from industrial sources.

i. Activated Sludge

In the activated sludge process, the dispersed-growth reactor is an aeration tank or basin containing a suspension of the wastewater and microorganisms, the mixed liquor. The contents of the aeration tank are mixed vigorously by aeration devices which also supply oxygen to the biological suspension. Aeration devices commonly used include submerged diffusers that release compressed air and mechanical surface aerators that introduce air by agitating the liquid surface. Hydraulic retention time in the aeration tanks usually ranges from 3 to 8 hours but can be higher with high BOD₅ wastewaters. Following the aeration step, the microorganisms are separated from the liquid by sedimentation and the clarified liquid is secondary effluent. A portion of the biological sludge is recycled to the aeration basin to maintain a high mixed-liquor suspended solids (MLSS) level. The remainder is removed from the process and sent to sludge processing to maintain a relatively constant concentration of microorganisms in the system. Several variations of the basic activated sludge process, such as extended aeration and oxidation ditches, are in common use, but the principles are similar.

ii. Trickling Filters

A trickling filter or biofilter consists of a basin or tower filled with support media such as stones, plastic shapes, or wooden slats. Wastewater is applied intermittently, or sometimes continuously, over the media. Microorganisms become attached to the media and form a biological layer or fixed film. Organic matter in the wastewater diffuses into the film, where it is metabolized. Oxygen is normally supplied to the film by the natural flow of air either up or down through the media, depending on the relative temperatures of the wastewater and ambient air. Forced air can also be supplied by blowers but this is rarely necessary. The thickness of the biofilm increases as new organisms grow. Periodically, portions of the film 'slough off' the media. The sloughed material is separated from the liquid in a secondary clarifier and discharged to sludge processing. Clarified liquid from the secondary clarifier is the secondary effluent and a portion is often recycled to the biofilter to improve hydraulic distribution of the wastewater over the filter.

iii. Rotating Biological Contactors

Rotating biological contactors (RBCs) are fixed-film reactors similar to biofilters in that organisms are attached to support media. In the case of the RBC, the support media are slowly rotating discs that are partially submerged in flowing wastewater in the reactor. Oxygen is supplied to the attached biofilm from the air when the film is out of the water and from the liquid when submerged, since oxygen is transferred to the wastewater by surface turbulence created by the discs' rotation. Sloughed pieces of biofilm are removed in the same manner described for biofilters.

High-rate biological treatment processes, in combination with primary sedimentation, typically remove 85 % of the BOD₅ and SS originally present in the raw wastewater and some of the heavy metals. Activated sludge generally produces an effluent of slightly higher quality, in terms of these constituents, than biofilters or RBCs. When coupled with a disinfection step, these processes can provide substantial but not complete removal of bacteria and virus. However, they remove very little phosphorus, nitrogen, non-biodegradable organics, or dissolved minerals.

3.2.4 Tertiary and/or advanced treatment

Tertiary and/or advanced wastewater treatment is employed when specific wastewater constituents which cannot be removed by secondary treatment must be removed. As shown in Figure 3, individual treatment processes are necessary to remove nitrogen, phosphorus, additional suspended solids, refractory organics, heavy metals and dissolved solids. Because advanced treatment usually follows high-rate secondary treatment, it is sometimes referred to as tertiary treatment. However, advanced treatment processes are sometimes combined with primary or secondary treatment (e.g., chemical addition to primary clarifiers or aeration basins to remove phosphorus) or used in place of secondary treatment (e.g., overland flow treatment of primary effluent).

An adaptation of the activated sludge process is often used to remove nitrogen and phosphorus and an example of this approach is the 23 Ml/d treatment plant commissioned in 1982 in British Columbia, Canada (World Water 1987). The Bardenpho Process adopted is shown in simplified form in Figure 6. Effluent from primary clarifiers flows to the biological reactor, which is physically divided into five zones by baffles and weirs. In sequence these zones are: (i) anaerobic fermentation zone (characterized by very low dissolved oxygen levels and the absence of nitrates); (ii) anoxic zone (low dissolved oxygen levels but nitrates present); (iii) aerobic zone (aerated); (iv) secondary anoxic zone; and (v) final aeration zone. The function of the first zone is to condition the group of bacteria responsible for phosphorus removal by stressing them under low oxidation-reduction conditions, which results in a release of phosphorus equilibrium in the

cells of the bacteria. On subsequent exposure to an adequate supply of oxygen and phosphorus in the aerated zones, these cells rapidly accumulate phosphorus considerably in excess of their normal metabolic requirements. Phosphorus is removed from the system with the waste activated sludge.

Most of the nitrogen in the influent is in the ammonia form, and this passes through the first two zones virtually unaltered. In the third aerobic zone, the sludge age is such that almost complete nitrification takes place, and the ammonia nitrogen is converted to nitrites and then to nitrates. The nitrate-rich mixed liquor is then recycled from the aerobic zone back to the first anoxic zone. Here denitrification occurs, where the recycled nitrates, in the absence of dissolved oxygen, are reduced by facultative bacteria to nitrogen gas, using the influent organic carbon compounds as hydrogen donors. The nitrogen gas merely escapes to atmosphere. In the second anoxic zone, those nitrates which were not recycled are reduced by the endogenous respiration of bacteria. In the final re-aeration zone, dissolved oxygen levels are again raised to prevent further denitrification, which would impair settling in the secondary clarifiers to which the mixed liquor then flows.

An experimentation programme on this plant demonstrated the importance of the addition of volatile fatty acids to the anaerobic fermentation zone to achieve good phosphorus removal. These essential short-chain organics (mainly acetates) are produced by the controlled fermentation of primary sludge in a gravity thickener and are released into the thickener supernatant, which can be fed to the head of the biological reactor. Without this supernatant return flow, overall phosphorus removal quickly dropped to levels found in conventional activated sludge plants. Performance data over three years have proved that, with thickener supernatant recycle, effluent quality median values of 0.5-1.38 mg/l Ortho-P, 1.4-1.6 mg/l Total nitrogen and 1.4-2.0 mg/l nitrate-N are achievable. This advanced biological wastewater treatment plant cost only marginally more than a conventional activated sludge plant but nevertheless involved considerable investment. Furthermore, the complexity of the process and the skilled operation required to achieve consistent results make this approach unsuitable for developing countries.

In many situations, where the risk of public exposure to the reclaimed water or residual constituents is high, the intent of the treatment is to minimize the probability of human exposure to enteric viruses and other pathogens. Effective disinfection of viruses is believed to be inhibited by suspended and colloidal solids in the water, therefore these solids must be removed by advanced treatment before the disinfection step. The sequence of treatment often specified in the United States is: secondary treatment followed by chemical coagulation, sedimentation, filtration, and disinfection. This level of treatment is assumed to

produce an effluent free from detectable viruses. Effluent quality data from selected advanced wastewater treatment plants in California are reported in Table 14. In Near East countries adopting tertiary treatment, the tendency has been to introduce pre-chlorination before rapid-gravity sand filtration and post-chlorination afterwards. A final ozonation treatment after this sequence has been considered in at least one country.

3.2.5 Disinfection

Disinfection normally involves the injection of a chlorine solution at the head end of a chlorine contact basin. The chlorine dosage depends upon the strength of the wastewater and other factors, but dosages of 5 to 15 mg/l are common. Ozone and ultra violet (uv) irradiation can also be used for disinfection but these methods of disinfection are not in common use. Chlorine contact basins are usually rectangular channels, with baffles to prevent short-circuiting, designed to provide a contact time of about 30 minutes. However, to meet advanced wastewater treatment requirements, a chlorine contact time of as long as 120 minutes is sometimes required for specific irrigation uses of reclaimed wastewater. The bactericidal effects of chlorine and other disinfectants are dependent upon pH, contact time, organic content, and effluent temperature.

3.2.6 Effluent storage

Although not considered a step in the treatment process, a storage facility is, in most cases, a critical link between the wastewater treatment plant and the irrigation system. Storage is needed for the following reasons:

- i. To equalize daily variations in flow from the treatment plant and to store excess when average wastewater flow exceeds irrigation demands; includes winter storage.
- ii. To meet peak irrigation demands in excess of the average wastewater flow.
- iii. To minimize the effects of disruptions in the operations of the treatment plant and irrigation system. Storage is used to provide insurance against the possibility of unsuitable reclaimed wastewater entering the irrigation system and to provide additional time to resolve temporary water quality problems.