

An anoxic zone is defined as one where no free oxygen is available, i.e. the measurable DO level in the liquid is zero, and thus respiring organisms are forced to utilise the nitrate present as an oxygen source. They are normally generated at the influent end of the plant, where RAS and settled sewage or industrial effluent are mixed but not aerated. The high oxygen demand of actively respiring RAS and the BOD demand of settled influent quickly consume any free oxygen.

In the lack of a separate, small tank of short retention time the first lane, or part of it, in the aeration plant can be made anoxic. To avoid settlement, submerged propeller stirrers are used to keep solids in suspension and assist the forward flow of the liquid. Typically, a 50 per cent reduction in effluent nitrate can be achieved. Adequate DO monitoring is essential, coupled to mixer control.

Anoxic zones are used to control filamentous organism growth and thus bulking sludge successfully, and recent work indicates that careful design of the 'selectors' (small volume, short retention tanks) at the influent end can assist with controlling surface foam.

Some of the earliest work was done at Rye Meads by simply removing and blanking off half of the diffused air domes in the first lane of the aeration plant. Subsequently, anoxic zones were generated in other lanes experimentally although most contemporary activated sludge plants generate one zone at the influent end only. The operating parameters for extended aeration are, however, deliberately designed to generate anoxic conditions at several points in the aeration tank and are therefore quite different, as described in the next section.

Shock loads and toxic discharges

Activated sludge, like any other biological water treatment system, operates best under stable conditions, but even settled sewage varies in strength by a factor of 2:1 over a 24 hour cycle, and in industrial environments, shock loads are a common event.

Organic load variations usually present the problem of fluctuating oxygen demand and DO levels in the tank and varying sludge settling characteristics. Changes to nutrient ratios are more difficult to monitor continuously, but are equally likely to affect DO levels and favour rapid growth of particular organisms. Sludge bulking, caused by proliferation of the organism *Sphaerotilus natans*, can occur very rapidly at a sewage works receiving, for example, a sudden discharge of carbohydrate waste from a sweet factory.

Although some adaptability may be bred into the biomass, toxic organics such as chlorinated hydrocarbons, and toxic metals are likely to have a devastating effect on satisfactory operation. The degree of effect will depend on the mass of toxic material in relation to the total activated sludge plant volume. Common toxic metal levels above 5 mg/l in the aeration plant are likely to exceed the buffering capacity and any inherent biological resilience. A rapid deterioration of both effluent quality and sludge settling characteristics is very likely. Chlorinated hydrocarbons produce pronounced effects above 0.1 mg/l. In this respect, activated sludge is probably less hardy than the biofilter, where biomass turnover and metabolic rates are slower and more influenced by ambient temperatures, and biofilters often survive toxic discharges better than activated sludge.

Solutions to these problems include adequate numbers of strategically placed electrodes to monitor DO levels and a rapid response control system to alter aeration levels where organic load variation is likely. Nutrient ratio variations and toxic materials are best coped with by an upstream buffering or holding tank, apart from and preceding primary settlement and which is frequently monitored for likely toxics and/or nitrogen/phosphorus values as appropriate. Adjustment for the latter can then be made by dosing urea or phosphoric acid, respectively.

Biological Treatment of Hazardous and Biowastes

INTRODUCTION

Hazardous wastes is a term that was introduced in the 1970s to replace the term, toxic wastes. For years engineers and scientists recognised that specific compounds in gaseous, liquid and solid wastes were toxic to biological life. It was also recognised that toxic wastes required special handling and treatment before the waste materials could be returned to the environment. In effect, the toxic wastes needed to be converted to non-toxic compounds. Concentrated inorganic acid wastes, primarily sulphuric acid, nitric acid, hydrochloric acid, and hydrofluoric acid, had to be neutralised and diluted prior to discharge in the environment. Concentrated inorganic alkaline wastes, containing sodium hydroxide, calcium hydroxide, and magnesium hydroxide, also needed to be neutralised and diluted prior to discharge. The same was true of strong oxidizing compounds, such as chlorine and ozone. Strongly reduced compounds, such as hydrogen sulphide, required oxidation and dilution. One of the major problems with toxic wastes lay with the multitude of organic compounds that had varying degrees of toxicity. There were no simple methods to treat the toxic organic wastes. Unfortunately, too many industrial plants ignored their toxic wastes and created serious pollution problems. Rachel Carson's focused on the potential dangers of organic pesticides such as DDT, methoxychlor, chlordane, heptachlor, and benzene hexachloride.

A hazardous waste is waste that poses substantial or potential threat to public health or the environment. These wastes may be found in different physical states such as gases, liquids and solids. Furthermore, a hazardous waste is a special type of waste because it cannot be disposed of by common means like other by-products of our everyday lives.

Hazardous wastes have been defined by RCRA into four basic categories:

1. Ignitability poses a fire hazard during routine handling.
2. Corrosivity liquid wastes having a pH equal to or less than 2.0 or equal to or greater than 12.5.
3. Reactivity unstable material, reacts violently with water, produces toxic gases or is explosive.
4. Toxicity extractable material in water that is biologically toxic.

While these definitions cover the range of hazardous wastes, it soon became evident that these four groups are much too broad for day-to-day use. Many commonly used chemicals could be classified as 'hazardous' using this classification. In an effort to clarify what constitutes hazardous wastes, the EPA developed four lists of chemicals and materials that could be easily identified as being hazardous. The *F-list* contains hazardous wastes from non-specific sources and includes solvents used in degreasing, metal plating wastes and various chlorinated organics. The *K-list* contains hazardous wastes generated by specific industrial processes, such as, wood preservation, pigment production, chemical production,

petroleum refining, iron and steel production, explosives manufacturing, and pesticide production. The *K-list* includes specific discarded commercial chemical products, container residues, and spillages that are acutely toxic and are accumulated in amounts greater than 1.0 kg/month. The *U-list* is similar to the *P-list* except they can be accumulated up to 25 kg/month without regulation. The four lists of hazardous waste materials are sufficiently specific that both industries and regulatory agencies know what materials need to be examined under EPA regulations.

SOURCES OF HAZARDOUS WASTES

Hazardous wastes are produced from specific industrial operations. Like most industrial wastes, hazardous wastes can be created from the raw materials used in the industrial operations, from intermediates formed during the processing of raw materials, and even from the final products packaged for sale to the public. Most industrial plants do not plan on producing hazardous wastes since they create serious internal management problems. Yet, some plants cannot help but produce hazardous wastes in view of the raw materials they use, the intermediates they produce, and their final products. Most hazardous wastes produced inside industrial plants come from spills, leaks, and cleaning equipment and workspaces. Most consumer hazardous wastes come from discarding containers containing products having hazardous characteristics. Considerable efforts are being made to reduce consumer hazardous wastes by changing the formulations of products from hazardous materials to nonhazardous materials wherever possible. Many industries are changing raw materials and the production of specific intermediates to minimise the production of hazardous wastes. Unfortunately, the leaks and spills of hazardous materials from old chemical processes have created major hazardous waste problems that have yet to be fully addressed. Many of the industrial plants that created considerable hazardous wastes have closed operations; but the hazardous wastes remain in the soil around the old plants. Originally, hazardous wastes were believed to be largely solid wastes deposited in sanitary landfills. Many industries placed their hazardous wastes into steel barrels and buried them in either municipal landfills or industrial landfills. For this reason the early hazardous waste regulations were concerned with solid waste management. It did not take long before it was recognised that many of the hazardous wastes in the barrels were liquid wastes and semi-solid sludge. Over time the steel barrels began to leak and the apparent solid wastes became liquid wastes that moved out of the sanitary landfills into the groundwater that was being used for local water supply. It is currently recognised that hazardous wastes can include gaseous, liquid, or solid.

Treatment Concepts

It is important to understand how hazardous wastes can be treated if industries are to eliminate the production of hazardous wastes and if old hazardous waste sites are to be properly cleaned for reuse. Needless to say, understanding the chemical characteristics of the hazardous wastes is the first step of the treatment process. Next, it is necessary to recognise the required concentration of the hazardous wastes that can be safely discharged back into the environment. The difference between the initial concentration and the final concentration of the hazardous materials establishes the degree of treatment required. Treatment can be physical, chemical, or biological or a combination of these three. But here we are concerned only with biological treatment.

BIOLOGICAL TREATMENT

Biological treatment has been used for many years in the treatment of organic waste-waters containing hazardous materials. The chemical industry, petroleum refineries, and iron and steel mills have developed

a number of biological treatment systems to handle hazardous waste materials. Biological treatment systems have been developed for above ground systems and *in situ* systems. The above ground biological treatment systems are the easiest to design and to operate. The organic waste-waters from industrial plants are discharged into conventional or semi-conventional biological treatment systems. Activated sludge systems and high rate anaerobic systems have been used in the treatment of organic hazardous wastes. In plants where organic hazardous wastes have saturated the soil, the hazardous wastes have been pumped out of the ground for biological treatment. In a number of locations efforts have been directed towards *in situ* biological treatment rather than pumping and treating. *In situ* systems require the addition of nutrients and an oxygen source. Oxygen can come from diffused aeration or chemical oxygen, primarily hydrogen peroxide. Developing sufficient numbers of active, aerobic bacteria in the hazardous wastes located underground in the soil is a difficult process. The hazardous waste stream is normally pumped from the ground. The required chemicals are added and the wastes are pumped back into the ground. The major problem is proper distribution of the nutrients and the oxygen, if aerobic bacteria growth is desired. The injected liquid follows the path of least resistance in the soil. The path of least resistance may not be the desired path to reach the hazardous wastes. For many hazardous wastes it is necessary to develop a population of acclimated bacteria. Some *in situ* systems have used the natural soil bacteria as a starter with the hazardous wastes determining the specific bacteria for growth. Where natural bacteria have failed to develop, acclimated bacteria have been injected with the return liquid into the soil environment. Once the bacteria begin to develop, there is concern that the bacteria mass will bridge across soil particles and retard normal fluid flow. *In situ* treatment has had mixed results compared with the success of above ground treatment. Yet, the simplicity of *in situ* treatment has attracted considerable attention.

DEVELOPING BIOTREATMENT SYSTEMS FOR HAZARDOUS WASTE-WATER

Finding bacteria that can metabolise hazardous organic compounds is the first step in developing biological treatment systems to treat these materials in hazardous waste streams. Normally, the best source of bacteria is from soil around where the hazardous materials have been used in manufacturing. Most manufacturing plants have had spills and leaks from time to time. Equipment containing the hazardous materials is often washed outside of the normal manufacturing areas with some of the materials being absorbed by the soil. Over the years some hazardous materials have accumulated in the surrounding soil where they have stimulated limited growth of bacteria that can tolerate the toxic materials and can partially metabolise the toxic materials as a source of energy. Since soil often lacks sufficient nutrients for large populations of bacteria or fungi, metabolism of the toxic materials has been limited, allowing the toxic materials to accumulate with time. It is not surprising that large amounts of hazardous organic chemicals have been found in soil environment under a number of chemical plants. The concentration of toxic materials may have reached the level where all biological life is unable to survive in the contaminated soil. If this is the case, the desired bacteria can normally be found further from the high concentrations of toxic materials where the concentration of toxic chemicals begin to drop below the acutely toxic level and some acclimation has occurred in the soil. Examination of the bacteria populations in the surface soil along a line radiating from the manufacturing area can be a useful indicator of where to look for acclimated bacteria.

Simple bacteria plate counts can be used as a rough indicator of the bacteria populations in the soil. As the total number of bacteria per g soil rises, it indicates that the level of toxicity has diminished. When the bacteria population reaches its maximum level and remains steady as you move further from

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