Wastewater Treatment Methods & Disposal

Satisfactory disposal of wastewater, whether by surface, subsurface methods or dilution, is dependent on its treatment prior to disposal. Adequate treatment is necessary to prevent contamination of receiving waters to a degree which might interfere with their best or intended use, whether it be for water supply, recreation, or any other required purpose.

Wastewater treatment consists of applying known technology to improve or upgrade the quality of a wastewater. Usually wastewater treatment will involve collecting the wastewater in a central, segregated location (the Wastewater Treatment Plant) and subjecting the wastewater to various treatment processes. Most often, since large volumes of wastewater are involved, treatment processes are carried out on continuously flowing wastewaters (continuous flow or "open" systems) rather than as "batch" or a series of periodic treatment processes in which treatment is carried out on parcels or "batches" of wastewaters. While most wastewater treatment processes are continuous flow, certain operations, such as vacuum filtration, involving as it does, storage of sludge, the addition of chemicals, filtration and removal or disposal of the treated sludge, are routinely handled as periodic batch operations.

Wastewater treatment, however, can also be organized or categorized by the nature of the treatment process operation being used; for example, physical, chemical or biological. Examples of these treatment steps are shown below. A complete treatment system may consist of the application of a number of physical, chemical and biological processes to the wastewater.

Some Physical, Chemical and Biological Wastewater Treatment Methods

PHYSICAL	CHEMICAL	BIOLOGICAL
Sedimentation (Clarification)	Chlorination	Aerobic
Screening	Ozonation	Activated Sludge
Aeration	Neutralization	Treatment Methods
Filtration	Coagulation	Trickling Filtration
Flotation and	Adsorption	Oxidation Ponds
Skimming	Ion Exchange	Lagoons
Degasification		Aerobic Digestion
Equalization		Anaerobic
Ultra-Violet		Anaerobic Digestion
		Septic Tanks
		Lagoons

Photo Credit: Virginia Department of Health

Physical methods include processes where no gross chemical or biological changes are carried out and strictly physical phenomena are used to improve or treat the wastewater. Examples would be coarse screening to remove larger entrained objects and sedimentation (or clarification).

In the process of sedimentation, physical phenomena relating to the settling of solids by gravity are allowed to operate. Usually this consists of simply holding a wastewater for a short period of time in a tank under quiescent conditions, allowing the heavier solids to settle, and removing the "clarified" effluent. Sedimentation for solids separation is a very common process operation and is routinely employed at the beginning and end of wastewater treatment operations. While sedimentation is one of the most common physical treatment processes that is used to achieve treatment, another physical treatment process consists of aeration -- that is, physically adding air, usually to provide oxygen to the wastewater. Still other physical phenomena used in treatment consists of filtration. Here wastewater is passed through a filter medium to separate solids. An example would be the use of sand filters to further remove entrained solids from a treated wastewater. Certain phenomena will occur during the sedimentation process and can be advantageously used to further improve water quality. Permitting greases or oils, for example, to float to the surface and skimming or physically removing them from the wastewaters is often carried out as part of the overall treatment process.

In certain industrial wastewater treatment processes strong or undesirable wastes are sometimes produced over short periods of time. Since such "slugs" or periodic inputs of such wastes would damage a biological treatment process, these wastes are sometimes held, mixed with other wastewaters, and gradually released, thus eliminating "shocks" to the treatment plant. This is call equalization. Another type of "equalization" can be used to even out wide variations in flow rates. For example, the wet well of a pump station can receive widely varying amounts of wastewater and, in turn, pump the wastes onward at more uniform rates.

Ultraviolet sterilization or UV is an invisible radiation that kills microorganisms; however, the UV rays must actually strike the cell to be effective. UV radiation penetrates the outer membrane of the cell, passes through the cell structure and disrupts its DNA, thus preventing reproduction. The use of UV technology does not alter the water's chemical balance. Nothing is added to the water or removed because the sterilized microorganisms remain in the water.

The effectiveness of the UV process depends upon the dose of ultraviolet radiation directly applied to the water, and exposure time of the generated radiation, which is measured in microwatt seconds per square centimeter (mws/cm2).

Generally, UV systems are designed to provide a dosage greater than 30,000 mws/cm2 during one year of continuous operation. It is important to know that UV sterilization does not effectively disinfect some organisms such as cysts of Giardia, Cryptosporidium, molds and protozoa.

Important variables for successful disinfection

The best that UV can hope for is to achieve 99.9% (3 log) reduction in micro- organisms in certain applications and with proper maintenance. In order for a UV unit to successfully disinfect water, the following variables must be considered:

Water Quality

Certain contaminants in water can reduce the transmission of UV light through the water, which reduces the UV effectiveness to reach the bacteria. These UV absorbing contaminants include turbidity, iron, and humic and fulvic acid. Suspended particles are a problem because microorganisms buried within particles are shielded from the UV light.

The barrier created with the UF membrane can achieve a 99.9999% (6 log) reduction in microorganisms. Anything larger than the pores on the surface of the membrane will be rejected.

UV disinfection is most effective for treating water that has been filtered adequately for suspended solids or where the water has first passed through a reverse osmosis system.

Recommended Maximum Concentration Levels for Water to be Treated By UV

Turbidity	5 NTU
Suspended Solids	10 mg/l
Color	None
Iron	0.3 mg/l
Manganese	0.05 mg/l
pH	6.5 – 9.5
Hardness	< 6 grains

UV units have a minimum and maximum flow rate capacity. If the flow is too high, water will pass through without enough UV radiation to be effective. If the flow is too low, heat may build up which can increase the water temperature and damage the UV lamp.

Limitations of UV treatment

Only under ideal conditions can a UV system provide 99.9% reduction of all bacteria. Even with this performance, ultraviolet disinfection has the following limitations:

The Disinfection Point:

UV units only kill bacteria at one point in a watering system and do not provide any residual germicidal effect downstream. If just one bacterium passes through unharmed (100% destruction of bacteria cannot be guaranteed), there is nothing to prevent it from attaching to downstream piping surfaces and proliferating.

Cells Not Removed

Bacteria cells are not removed in a UV unit but are converted into pyrogens. The converted microorganisms and any other contaminants in the water are a food source for any bacteria that do survive downstream of the UV unit.

This results in the need for periodic disinfection of piping in a water treatment system disinfected by UV sterilization.

Lamp Replacement

UV lamps require replacement every 12 months whether the lamp stays on the entire time or it is turned on and off during this period. The UV lamps will solarize, thus reducing their intensity to about 60% of a new lamp after about one year of continuous use. When lamps are new, they will generate a dosage level near 60,000 mW-s/cm2. When the dosage drops to 30,000 mW-s/cm2 (the minimum dosage needed to effectively kill bacteria) lamps should be replaced. Lamp life will be shortened significantly if the lamp is turned on and off more frequently than once every eight hours.

Cleaning

As water passes through the UV unit, minerals in the water will scale out and build up on the quartz or Teflon sleeve. This will limit the penetration of UV rays through the sleeve and into the water. To maintain high clarity, the glass around the lamp must be cleaned regularly. Cleaning frequency depends upon the water quality and will be minimal with the use of a water softener or RO system.

Effectiveness

It should never be assumed a UV system keeps the water totally bacteria free. The UV unit may be working as specified killing 99.9% or more of the bacteria; however, if just one microorganism passes through the unit unharmed, there is nothing to prevent it from attaching to downstream piping surfaces and multiplying.

Chemical treatment consists of using some chemical reaction or reactions to improve the water quality. Probably the most commonly used chemical process is chlorination. Chlorine, a strong oxidizing chemical, is used to kill bacteria and to slow down the rate of decomposition of the wastewater. Bacterial kill is achieved when vital biological processes are affected by the chlorine. Another strong oxidizing agent that has also been used as an oxidizing disinfectant is ozone.

A chemical process commonly used in many industrial wastewater treatment operations is neutralization. Neutralization consists of the addition of acid or base to adjust pH levels back to neutrality. Since lime is a base it is sometimes used in the neutralization of acid wastes.

Coagulation consists of the addition of a chemical that, through a chemical reaction, forms an insoluble end product that serves to remove substances from the wastewater. Polyvalent metals are commonly used as coagulating chemicals in wastewater treatment and typical coagulants would include lime (that can also be used in neutralization), certain iron containing compounds (such as ferric chloride or ferric sulfate) and alum (aluminum sulfate).

Certain processes may actually be physical and chemical in nature. The use of activated carbon to "adsorb" or remove organics, for example, involves both chemical and physical processes. Processes such as ion exchange, which involves exchanging certain ions for others, are not used to any great extent in wastewater treatment.

Biological treatment methods use microorganisms, mostly bacteria, in the biochemical decomposition of wastewaters to stable end products. More microorganisms, or sludges, are formed and a portion of the waste is converted to carbon dioxide, water and other end products. Generally, biological treatment methods can be divided into aerobic and anaerobic methods, based on availability of dissolved oxygen.

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The purpose of wastewater treatment is generally to remove from the wastewater enough solids to permit the remainder to be discharged to a receiving water without interfering with its best or proper use. The solids which are removed are primarily organic but may also include inorganic solids. Treatment must also be provided for the solids and liquids which are removed as sludge. Finally, treatment to control odors, to retard biological activity, or destroy pathogenic organisms may also be needed.

While the devices used in wastewater treatment are numerous and will probably combine physical, chemical and biological methods, they may all be generally grouped under six methods:

1. Preliminary Treatment
2. Primary Treatment
3. Secondary Treatment
4. Disinfection
5. Sludge Treatment
6. Tertiary Treatment

Degrees of treatment are sometimes indicated by use of the terms primary, secondary and tertiary treatment. Tertiary treatment, properly, would be any treatment added onto or following secondary treatment.

Preliminary Treatment

At most plants preliminary treatment is used to protect pumping equipment and facilitate subsequent treatment processes. Preliminary devices are designed to remove or cut up the larger suspended and floating solids, to remove the heavy inorganic solids, and to remove excessive amounts of oils or greases.

To effect the objectives of preliminary treatment, the following devices are commonly used:

1. Screens -- rack, bar or fine
2. Comminuting devices -- grinders, cutters, shredders
3. Grit chambers
4. Pre-aeration tanks

In addition to the above, chlorination may be used in preliminary treatment. Since chlorination may be used at all stages in treatment, it is considered to be a method by itself. Preliminary treatment devices require careful design and operation.

Primary Treatment

In this treatment, most of the settleable solids are separated or removed from the wastewater by the physical process of sedimentation. When certain chemicals are used with primary sedimentation tanks, some of the colloidal solids are also removed. Biological activity of the wastewater in primary treatment is of negligible importance.

The purpose of primary treatment is to reduce the velocity of the wastewater sufficiently to permit solids to settle and floatable material to surface. Therefore, primary devices may consist of settling tanks, clarifiers or sedimentation tanks. Because of variations in design, operation, and application, settling tanks can be divided into four general groups:

1. Septic tanks
2. Two story tanks -- Imhoff and several proprietary or patented units
3. Plain sedimentation tank with mechanical sludge removal
4. Upward flow clarifiers with mechanical sludge removal

When chemicals are used, other auxiliary units are employed. These are:

1. Chemical feed units
2. Mixing devices
3. Flocculators

The results obtained by primary treatment, together with anaerobic sludge digestion as described later, are such that they can be compared with the zone of degradation in stream self-purification. The use of chlorine with primary treatment is discussed under the section on Preliminary Treatment.

Secondary Treatment

Secondary treatment depends primarily upon aerobic organisms which biochemically decompose the organic solids to inorganic or stable organic solids. It is comparable to the zone of recovery in the self-purification of a stream. The devices used in secondary treatment may be divided into four groups:

1. Trickling filters with secondary settling tanks
2. Activated sludge and modifications with final settling tanks
3. Intermittent sand filters
4. Stabilization ponds

The use of chlorine with secondary treatment is discussed under the section on Secondary Treatment

Chlorination

This is a method of treatment which has been employed for many purposes in all stages in wastewater treatment, and even prior to preliminary treatment. It involves the application of chlorine to the wastewater for the following purposes:

1. Disinfection or destruction of pathogenic organisms
2. Prevention of wastewater decomposition --

   (a) odor control, and
   (b) protection of plant structures

3. Aid in plant operation --

   (a) sedimentation,
   (b) tricklingfilters,
   (c) activated sludge bulking

4. Reduction or delay of biochemical oxygen demand (BOD)

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While chlorination has been commonly used over the years, especially for disinfection, other methods to achieve disinfection as well as to achieve similar treatment ends are also used. Among the most common is the use of ozone. In view of the toxicity of chlorine and chlorinated compounds for fish as well as other living forms, ozonation may be more commonly used in the future. This process will be more fully discussed in the section on disinfection.

Sludge Treatment

The solids removed from wastewater in both primary and secondary treatment units, together with the water removed with them, constitute wastewater sludge. It is generally necessary to subject sludge to some treatment to prepare or condition it for ultimate disposal. Such treatment has two objectives -- the removal of part or all of the water in the sludge to reduce its volume, and the decomposition of the putrescible organic solids to mineral solids or to relatively stable organic solids. This is accomplished by a combination of two or more of the following methods:

1. Thickening
2. Digestion with or without heat
3. Drying on sand bed -- open or covered
4. Conditioning with chemicals
5. Elutriation
6. Vacuum filtration
7. Heat drying
8. Incineration
9. Wet oxidation
10. Centrifuging

Package Units The term "package units" is used in the field to describe equipment which has been put on the market by a number of manufacturers that is intended to provide wastewater treatment by the use of prefabricated or modular units. Package units can also refer to a complete installation, including both mechanisms and prefabricated containers. This term is also applied to installations where only the mechanisms are purchased and the containers constructed by the purchaser in accordance with plans and specifications prepared by the manufacturer.

Though specific limitations have not been established, individual package units have, in general, been small installations serving a limited population.

Package units have been adapted to practically all the treatment devices, either singly or in various combinations that have been mentioned.

Tertiary and Advanced Wastewater Treatment

The terms "primary" and "secondary" treatment have been used to generally describe a degree of treatment; for example, settling and biological wastewater treatment. Since the early 1970's "tertiary" treatment has come into use to describe additional treatment following secondary treatment. Quite often this merely indicates the use of intermittent sand filters for increased removal of suspended solids from the wastewater. In other cases, tertiary treatment has been used to describe processes which remove plant nutrients, primarily nitrogen and phosphorous, from wastewater.

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Improvement and upgrading of wastewater treatment units as well as the need to minimize environmental effects has led to the increased use of tertiary treatment.

A term that is also sometimes used to indicate treatment of a wastewater by methods other than primary or biological (secondary) treatment is advanced treatment. This degree of treatment is usually achieved by chemical (for example coagulation) methods as well as physical methods (flocculation, settling and activated carbon adsorption) to produce a high quality effluent water.

http://www.cdc.gov/healthywater/drinking/public/water_treatment.html