***Lec.4 Sewage treatment***

**Sewage** (**wastewater) treatment** is the process of removing [contaminants](https://en.wikipedia.org/wiki/Pollutant) from municipal [wastewater](https://en.wikipedia.org/wiki/Wastewater), containing mainly household [sewage](https://en.wikipedia.org/wiki/Sewage) plus some [industrial wastewater](https://en.wikipedia.org/wiki/Industrial_wastewater_treatment). Physical, chemical, and biological processes are used to remove contaminants and produce treated wastewater that is safe enough for release into the environment. A by-product of sewage treatment is a semi-solid waste or slurry, called [sewage sludge](https://en.wikipedia.org/wiki/Sewage_sludge). The sludge has to undergo further [treatment](https://en.wikipedia.org/wiki/Sewage_sludge_treatment) before being suitable for disposal or application to land.

For most cities, the [sewer system](https://en.wikipedia.org/wiki/Sanitary_sewer) will also carry a proportion of industrial effluent to the sewage treatment plant which has usually received pre-treatment at the factories themselves to reduce the pollutant load. If the sewer system is a [combined sewer](https://en.wikipedia.org/wiki/Combined_sewer) then it will also carry  storm water runoff to the sewage treatment plant. The first part of filtration of sewage typically includes a [bar screen](https://en.wikipedia.org/wiki/Bar_screen) to filter solids and large objects which are then collected in [dumpsters](https://en.wikipedia.org/wiki/Dumpster) and disposed of in landfills, [fat](https://en.wikipedia.org/wiki/Fat) and [grease](https://en.wikipedia.org/wiki/Grease_%28lubricant%29) is also removed before the primary treatment of sewage.

***Sewage pretreatment*:**

Pretreatment removes all materials that can be easily collected from the raw sewage before they damage the pumps and sewage lines of primary treatment [clarifiers](https://en.wikipedia.org/wiki/Clarifier). Objects commonly removed during pretreatment include trash, tree limbs, leaves...etc.

The influent in sewage water passes through a [bar screen](https://en.wikipedia.org/wiki/Bar_screen) to remove all large objects like cans, sticks, plastic packets etc. carried in the sewage stream. The raking action of a mechanical bar screen is typically paced according to the accumulation on the bar screens flow rate; the solids are collected and later disposed. Bar screens of varying sizes may be used to optimize solids removal. If gross solids are not removed, they become entrained in pipes and moving parts of the treatment plant, and can cause substantial damage and inefficiency in the process.

***Grit removal:***

Pretreatment may include a sand or grit channel or chamber, where the velocity of the incoming sewage is adjusted to allow the settlement of sand, grit, stones, and broken glass. These particles are removed because they may damage pumps and other equipment. Grit chambers come in three types: horizontal grit chambers, aerated grit chambers and vortex grit chambers.

***Fat and grease removal:***

In some larger plants, [fat](https://en.wikipedia.org/wiki/Fat) and [grease](https://en.wikipedia.org/wiki/Grease_%28lubricant%29) are removed by passing the sewage through a small tank where skimmers collect the fat floating on the surface. Many plants, however, use primary clarifiers with mechanical surface skimmers for fat and grease removal.

***Primary treatment:***

In the primary [sedimentation](https://en.wikipedia.org/wiki/Sedimentation_%28water_treatment%29) stage, sewage flows through large tanks, "primary sedimentation tanks". The tanks are used to settle sludge while grease and oils rise to the surface and are skimmed off. Primary settling tanks are usually equipped with mechanically driven scrapers that continually drive the collected sludge towards a hopper in the base of the tank where it is pumped to sludge treatment facilities. Grease and oil from the floating material can sometimes be recovered for [saponification](https://en.wikipedia.org/wiki/Saponification) (soap making).

***Secondary treatment:***

[Secondary treatment](https://en.wikipedia.org/wiki/Secondary_treatment) is designed to substantially degrade the biological content of the sewage which is derived from human waste, food waste, soaps and detergent. The majority of municipal plants treat the settled sewage liquor using aerobic biological processes, to be effective, the [biota](https://en.wikipedia.org/wiki/Biota_%28ecology%29) require both [oxygen](https://en.wikipedia.org/wiki/Oxygen) and food to live. The [bacteria](https://en.wikipedia.org/wiki/Bacteria) and [protozoa](https://en.wikipedia.org/wiki/Protozoa) consume biodegradable soluble organic contaminants (e.g. [sugars](https://en.wikipedia.org/wiki/Sugar), fats, organic short-chain [carbon](https://en.wikipedia.org/wiki/Carbon) molecules) and bind much of the less soluble fractions into [floc](https://en.wikipedia.org/wiki/Flocculation%22%20%5Co%20%22Flocculation).

Secondary treatment systems are classified as fixed-film or suspended-growth systems.

Suspended-growth systems include [activated sludge](https://en.wikipedia.org/wiki/Activated_sludge), where the biomass is mixed with the sewage and can be operated in a smaller space than trickling filters that treat the same amount of water. However, fixed-film systems are more able to cope with drastic changes in the amount of biological material and can provide higher removal rates for organic material and suspended solids than suspended growth systems

Some secondary treatment methods include a secondary clarifier to settle out and separate biological floc or filter material grown in the secondary treatment bioreactor.

***List of process types:***  (a) Activated sludge (b) Aerated lagoon (c) Aerobic granulation (d) Constructed wetland (e) Membrane bioreactor.

To uses less space treat difficult waste, and intermittent flows, a number of designs of hybrid treatment plants have been produced.

***Tertiary treatment:***

The purpose of tertiary treatment is to provide a final treatment stage to further improve the effluent quality before it is discharged to the receiving environment (sea, river, lake, wet lands, etc.). More than one tertiary treatment process may be used at any treatment plant. If disinfection is practiced, it is always the final process. It is also called "effluent polishing".

***Filtration:***

[Sand filtration](https://en.wikipedia.org/wiki/Sand_filter) removes much of the residual suspended matter, filtration over [activated carbon](https://en.wikipedia.org/wiki/Activated_carbon), also called *carbon adsorption,* removes residual [toxins](https://en.wikipedia.org/wiki/Toxin).

***Lagoons or ponds:***

Lagoons or ponds providesettlement and further biological improvement of wastewater may be achieved through storage in large man-made ponds or lagoons. These lagoons are highly aerobic and colonization by native [macrophytes](https://en.wikipedia.org/wiki/Macrophyte%22%20%5Co%20%22Macrophyte), especially reeds, is often encouraged. Small filter-feeding [invertebrates](https://en.wikipedia.org/wiki/Invertebrate) such as [*Daphnia*](https://en.wikipedia.org/wiki/Daphnia) and species of *[Rotifera](https://en.wikipedia.org/wiki/Rotifera%22%20%5Co%20%22Rotifera)* greatly assist in treatment by removing fine particulates.

***Biological nutrient removal:***

Biological nutrient removal (BNR) is regarded by some as a type of secondary treatment process, and by others as a tertiary (or "advanced") treatment process. Wastewater may contain high levels of the nutrients [nitrogen](https://en.wikipedia.org/wiki/Nitrogen) and [phosphorus](https://en.wikipedia.org/wiki/Phosphorus). Excessive release to the environment can lead to a buildup of nutrients, called [eutrophication](https://en.wikipedia.org/wiki/Eutrophication), which can in turn encourage the overgrowth of weeds, [algae](https://en.wikipedia.org/wiki/Algae), and [cyanobacteria](https://en.wikipedia.org/wiki/Cyanobacteria) (blue-green algae). This may cause an [algal bloom](https://en.wikipedia.org/wiki/Algal_bloom), a rapid growth in the population of algae. The algae numbers are unsustainable and eventually most of them die. The decomposition of the algae by bacteria uses up so much of the oxygen in the water that most or all of the animals die, which creates more organic matter for the bacteria to decompose. In addition to causing deoxygenation, some algal species produce toxins that contaminate [drinking water](https://en.wikipedia.org/wiki/Drinking_water) supplies. Different treatment processes are required to remove nitrogen and phosphorus.

***Nitrogen removal:*** Nitrogen is removed through the biological [oxidation](https://en.wikipedia.org/wiki/Redox) of nitrogen from [ammonia](https://en.wikipedia.org/wiki/Ammonia) to [nitrate](https://en.wikipedia.org/wiki/Nitrate) ([nitrification](https://en.wikipedia.org/wiki/Nitrification)), followed by [denitrification](https://en.wikipedia.org/wiki/Denitrification%22%20%5Co%20%22Denitrification), the reduction of nitrate to nitrogen gas. Nitrogen gas is released to the atmosphere and thus removed from the water.

Nitrification itself is a two-step aerobic process, each step facilitated by a different type of bacteria. The oxidation of ammonia (NH3) to nitrite (NO2−) is most often facilitated by *Nitrosomonas* spp. Nitrite oxidation to nitrate (NO3−), though traditionally believed to be facilitated by *Nitrobacter* spp., is now known to be facilitated in the environment almost exclusively by *Nitrospira* spp. Sometimes the conversion of toxic ammonia to nitrate alone is referred to as tertiary treatment.

***Phosphorus removal:***

Phosphorus removal is important as it is a limiting nutrient for algae growth in many fresh water systems. It is also particularly important for water reuse systems where high phosphorus concentrations may lead to fouling of downstream equipment such as [reverse osmosis](https://en.wikipedia.org/wiki/Reverse_osmosis). Phosphorus can be removed biologically in a process called [enhanced biological phosphorus removal](https://en.wikipedia.org/wiki/Enhanced_biological_phosphorus_removal). In this process, specific bacteria, called [polyphosphate-accumulating organisms](https://en.wikipedia.org/wiki/Polyphosphate-accumulating_organisms) are selectively enriched and accumulate large quantities of phosphorus within their cells. When the biomass enriched in these bacteria is separated from the treated water, these [bio-solids](https://en.wikipedia.org/wiki/Biosolids) have a high [fertilizer](https://en.wikipedia.org/wiki/Fertilizer) value. Phosphorus removal can also be achieved by chemical [precipitation](https://en.wikipedia.org/wiki/Precipitation_%28chemistry%29), usually with [ferric chloride](https://en.wikipedia.org/wiki/Ferric_chloride) or [aluminum](https://en.wikipedia.org/wiki/Aluminum) .

***Disinfection****:*

The purpose of [disinfection](https://en.wikipedia.org/wiki/Disinfection) in the treatment of waste water is to substantially reduce the number of [microorganisms](https://en.wikipedia.org/wiki/Microorganism) in the water to be discharged back into the environment for the later use of drinking, bathing, irrigation, etc. The effectiveness of disinfection depends on the quality of the water being treated (e.g., cloudiness, pH, etc.), the type of disinfection being used, the disinfectant dosage. Cloudy water will be treated less successfully, since solid matter can shield organisms, especially from [ultraviolet light](https://en.wikipedia.org/wiki/Ultraviolet_light) . Generally, short contact times, low doses and high flows all militate against effective disinfection. Common methods of disinfection include [ozone](https://en.wikipedia.org/wiki/Ozone), [chlorine](https://en.wikipedia.org/wiki/Chlorine), [ultraviolet light](https://en.wikipedia.org/wiki/Ultraviolet_light), or [sodium hypochlorite](https://en.wikipedia.org/wiki/Sodium_hypochlorite). [Monochloramine](https://en.wikipedia.org/wiki/Monochloramine), which is used for drinking water, is not used in the treatment of waste water because of its persistence. After multiple steps of disinfection, the treated water is ready to be released back into the [water cycle](https://en.wikipedia.org/wiki/Water_cycle) by means of the nearest body of water or agriculture. Afterwards, the water can be transferred to reserves for everyday human uses.

[Chlorination](https://en.wikipedia.org/wiki/Water_chlorination) remains the most common form of waste water disinfection due to its low cost and long-term history of effectiveness. One disadvantage is that chlorination of residual organic material can generate chlorinated-organic compounds that may be [carcinogenic](https://en.wikipedia.org/wiki/Carcinogenic) or harmful to the environment. Residual chlorine may also be capable of chlorinating organic material in the natural aquatic environment. Further, because residual chlorine is toxic to aquatic species, the treated effluent must also be chemically dechlorinated.

[Ultraviolet](https://en.wikipedia.org/wiki/Ultraviolet) (UV) light can be used instead of chlorine, the treated water has no adverse effect on organisms that later consume it. UV radiation causes damage to the [genetic](https://en.wikipedia.org/wiki/Gene) structure of bacteria and [viruses](https://en.wikipedia.org/wiki/Virus) making them incapable of reproduction. The key disadvantages of UV disinfection are the need for frequent lamp maintenance and replacement and the need for a highly treated effluent to ensure that the target microorganisms are not shielded from the UV radiation.

[Ozone](https://en.wikipedia.org/wiki/Ozone) ([O](https://en.wikipedia.org/wiki/Oxygen)3) is generated by passing oxygen ([O](https://en.wikipedia.org/wiki/Oxygen)2) through a high [voltage](https://en.wikipedia.org/wiki/Voltage) potential resulting in a third oxygen [atom](https://en.wikipedia.org/wiki/Atom) becoming attached and forming [O](https://en.wikipedia.org/wiki/Oxygen)3. Ozone is very unstable and reactive and oxidizes most organic material it comes in contact with, thereby destroying many pathogenic microorganisms. Ozone is considered to be safer than chlorine because, unlike chlorine which has to be stored on site, ozone is generated on-site as needed from the oxygen in the ambient air.

***Fourth treatment stage:***

Micro-pollutants such as pharmaceuticals, ingredients of household chemicals, [environmental persistent pharmaceutical pollutants](https://en.wikipedia.org/wiki/Environmental_persistent_pharmaceutical_pollutant) or pesticides may not be eliminated in the conventional treatment process and therefore lead to [water pollution](https://en.wikipedia.org/wiki/Water_pollution). Although concentrations of those substances and their decomposition products are quite low, there is still a chance of harming aquatic organisms.

***Odor control***

[Odors](https://en.wikipedia.org/wiki/Odors) emitted by sewage treatment are typically an indication of an anaerobic or "septic" condition. Early stages of processing will tend to produce foul-smelling gases, with [hydrogen sulfide](https://en.wikipedia.org/wiki/Hydrogen_sulfide) being most common in generating complaints. Large process plants will often treat the odors with carbon reactors, small doses of [chlorine](https://en.wikipedia.org/wiki/Chlorine), or circulating fluids to biologically capture and metabolize the noxious gases. Other methods of odor control exist, including addition of iron salts, [hydrogen peroxide](https://en.wikipedia.org/wiki/Hydrogen_peroxide), [calcium nitrate](https://en.wikipedia.org/wiki/Calcium_nitrate), etc. to manage [hydrogen sulfide](https://en.wikipedia.org/wiki/Hydrogen_sulfide) levels.