Lecture 7
Water purification

Water purification

the process of removing undesirable chemicals, biological contaminants, suspended solids, and gases from water. The goal is to produce water fit for specific purposes. Most water is purified and disinfected for human consumption (drinking water), but water purification may also be carried out for a variety of other purposes, including medical, pharmacological, chemical, and industrial applications.

Water purification reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, and fungi as well as reduce the concentration of a range of dissolved and particulate matter.

The standards for drinking water quality are typically set by governments or by international standards. These standards usually include minimum and maximum concentrations of contaminants

The methods used include physical processes such as filtration, sedimentation, and distillation; biological processes such as slow sand filters or biologically active carbon; chemical processes such as flocculation and chlorination; and the use of electromagnetic radiation such as ultraviolet light.

Treatment

Pretreatment

1-**Pumping and containment** – The majority of water must be pumped from its source or directed into pipes or holding tanks.

2-Screening– The first step in purifying surface water is to remove large debris such as sticks, leaves, rubbish and other large particles which may interfere with subsequent purification steps .

3-Storage – Water from rivers may also be stored in bankside reservoirs for periods between a few days and many months to allow natural biological purification to take place. This is especially important if treatment is by slow sand filters.

4-Pre-chlorination – In many plants the incoming water was chlorinated to minimize the growth of fouling organisms on the pipe-work and tanks.

pH adjustment

Pure water has a pH close to 7. Sea water can have pH values that range from 7.5 to 8.4. Fresh water can have widely ranging pH values depending on the geology of the drainage basin or aquifer and the influence of contaminant inputs (acid rain).

If the water is acidic (lower than 7), **lime, soda ash, or sodium hydroxide** can be added to raise the pH during water purification processes. Lime addition increases the calcium ion concentration, thus raising the water hardness.

For highly acidic waters, forced draft **degasifies** can be an effective way to raise the pH, by stripping dissolved CO_2 from the water. Making the water alkaline helps coagulation and flocculation processes work effectively and also helps to minimize the risk of lead being dissolved from lead pipes. Sufficient alkalinity also reduces the corrosiveness of water to iron pipes. Acid (carbonic acid, hydrochloric acid or sulfuric acid) may be added to alkaline waters in some circumstances to lower the pH.

Coagulation and flocculation

One of the first steps in most conventional water purification processes is the addition of chemicals to assist in the removal of particles suspended in water. Particles can be inorganic such as clay and silt or organic such as algae, bacteria, viruses, protozoa and natural organic matter. Inorganic and organic particles contribute to the turbidity and color of water.

Coagulation (Colloidal Destabilization)

- It is the process of destabilization the colloids by adding chemicals (Coagulants) with a counter charge to neutralize the charge carried by the colloids. This will reduce the repelling force and gives the opportunity for the attractive forces to prevail and allow the particles and make them ready to agglomerate and form bigger particles.

Flocculation (Forming Flocs)

After destabilization, particles will be ready to a tract and agglomerate and form **flocs**. But this agglomeration is slow and they need help to accelerate this agglomeration. This help is called **Flocculation "**which is the slow stirring or gentle agitation to aggregate the destabilized particles and form a rapid settling floc".

Coagulants:

The chemicals added to water to destabilize colloids are called Coagulants. The most used in water treatment are:

- Aluminum Sulfate (Alum):
- Ferric Chloride
- Ferric sulfate :

Two key properties of Coagulants

• Should be nontoxic: health concern

• Trivalent ions: most efficient compared to mono and divalent **.**

Sedimentation

Waters exiting the flocculation basin may enter the sedimentation basin, also called a clarifier or settling basin. It is a large tank with low water velocities, allowing floc to settle to the bottom. The sedimentation basin is best located close to the flocculation basin so the transit between the two processes does not permit settlement or floc break up. Sedimentation basins may be rectangular, where water flows from end to end, or circular where flow is from the center outward. Sedimentation basin outflow is typically over a weir so only a thin top layer of water—that furthest from the sludge—exits.

Sludge storage and removal

As particles settle to the bottom of a sedimentation basin, a layer of sludge is formed on the floor of the tank which must be removed and treated. The amount of sludge generated is significant, often 3 to 5 percent of the total volume of water to be treated.

Floc blanket clarifiers

A subcategory of sedimentation is the removal of particulates by entrapment in a layer of suspended floc as the water is forced upward. The major advantage of floc blanket clarifiers is that they occupy a smaller footprint than conventional sedimentation. Disadvantages are that particle removal efficiency can be highly variable depending on changes in influent water quality and influent water flow rate.

Filtration

After separating most floc, the water is filtered as the final step to remove remaining suspended particles and unsettled floc.

Rapid sand filters

The most common type of filter is a rapid sand filter. Water moves vertically through sand which often has a layer of activated carbon or anthracite coal above the sand. The top layer removes organic compounds, which contribute to taste and odour. The space between sand particles is larger than the smallest suspended particles, so simple filtration is not enough. Most particles pass through surface layers but are trapped in pore spaces or adhere to sand particles. Effective filtration extends into the depth of the filter.

Advantages:

- Filters out much smaller particles than paper and sand filters can.
- Filters out virtually all particles larger than their specified pore sizes.
- They are quite thin and so liquids flow through them fairly rapidly.
- They are reasonably strong and so can withstand pressure differences across them of typically 2–5 atmospheres.
- They can be cleaned (back flushed) and reused

Slow sand filters

may be used where there is sufficient land and space, as the water flows very slowly through the filters. These filters rely on biological treatment processes for their action rather than physical filtration. They are carefully constructed using graded layers of sand, with the coarsest sand, along with some gravel, at the bottom and finest sand at the top. Drains at the base convey treated water away for disinfection. Filtration depends on the development of a thin biological layer, called the zoogleal layer, on the surface of the filter.. Slow sand filters are not backwashed; they are maintained by having the top layer of sand scraped off when flow is eventually obstructed by biological growth .

Membrane filtration

Membrane filters are widely used for filtering both drinking water and sewage. For drinking water, membrane filters can remove virtually all particles larger than 0.2 μm—including *giardia* and *cryptosporidium*. Membrane filters are an effective form of tertiary treatment when it is desired to reuse the water for industry, for limited domestic purposes, or before discharging the water into a river that is used by towns further downstream. They are widely used in industry, particularly for beverage preparation (including bottled water). However no filtration can remove substances that are actually dissolved in the water such as phosphates, nitrates and heavy metal ions.

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Removal of ions and other dissolved substances :

using method like :

Ultrafiltration membranes

Ion exchange:

Precipitative softening:

Electro deionization:

Disinfection

Disinfection is accomplished both by filtering out harmful micro-organisms and by adding disinfectant chemicals. Water is disinfected to kill any pathogens which pass through the filters and to provide a residual dose of disinfectant to kill or inactivate potentially harmful micro-organisms in the storage and distribution systems.

Possible pathogens include viruses, bacteria, *Salmonella*, *Cholera*, *Campylobacter* and *Shigella*, and protozoa, including *Giardia lamblia* and other *cryptosporidia*. After the introduction of any chemical disinfecting agent, the water is usually held in temporary storage – often called a contact tank or clear well – to allow the disinfecting action to complete.

Chlorine disinfection

The most common disinfection method involves some form of chlorine or its compounds such as chloramine or chlorine dioxide. Chlorine is a strong oxidant that rapidly kills many harmful micro-organisms. Because chlorine is a toxic gas, there is a danger of a release associated with its use. This problem is avoided by the use of sodium hypochlorite, which is a relatively inexpensive solution used in household bleach that releases free chlorine when dissolved in water... Chlorine levels up to 4 milligrams per liter (4 parts per million) are considered safe in drinking water potentially harmful chemical by-products. These by-products, trihalomethanes (THMs) and haloacetic acids (HAAs), are both carcinogenic in large quantities.. Although chlorine is effective in killing bacteria, it has limited effectiveness against pathogenic protozoa that form cysts in water such as *Giardia lamblia* and *Cryptosporidium*.

Chlorine dioxide disinfection

Chlorine dioxide is a faster-acting disinfectant than elemental chlorine. It is relatively rarely used because in some circumstances it may create excessive amounts of chlorite, which is a by-product regulated to low allowable levels in the United States. Chlorine dioxide can be supplied as an aqueous solution and added to water to avoid gas handling problems;

Chloramination

The use of chloramine is becoming more common as a disinfectant. Although chloramine is not as strong an oxidant, it provides a longer-lasting residual than free chlorine because of its lower redox potential compared to free chlorine. It is possible to convert chlorine to chloramine by adding ammonia to the water after adding chlorine. The chlorine and ammonia react to form chloramine.

Ozone disinfection

Ozone is an unstable molecule which readily gives up one atom of oxygen providing a powerful oxidizing agent which is toxic to most waterborne organisms. It is a very strong, broad spectrum disinfectant. Ozone disinfection, or ozonation, is an effective method to inactivate harmful protozoa that form cysts.. Ozone is made by passing oxygen through ultraviolet light or a "cold" electrical discharge. To use ozone as a disinfectant, it must be created on-site and added to the water by bubble contact. Some of the advantages of ozone include the production of fewer dangerous by-products and the absence of taste and odour problems (in comparison to chlorination). No residual ozone is left in the water. In the absence of a residual disinfectant in the water, chlorine or chloramine may be added throughout a distribution system to remove any potential pathogens in the distribution piping.

Ultraviolet disinfection

Ultraviolet light (UV) is very effective at inactivating cysts, in low turbidity water. UV light's disinfection effectiveness decreases as turbidity increases, a result of the absorption, scattering, and shadowing caused by the suspended solids. The main disadvantage to the use of UV radiation is that, like ozone treatment, it leaves no residual disinfectant in the water; therefore, it is sometimes necessary to add a residual disinfectant after the primary disinfection process. This is often done through the addition of chloramines, discussed above as a primary disinfectant.

Ionizing radiation : Like UV, **ionizing radiation** (X-rays, gamma rays, and electron beams) has been used to sterilize water.

Bromination and iodinization : Bromine and iodine can also be used as disinfectants. However, chlorine in water is over three times more effective as a disinfectant against *Escherichia coli* than an equivalent concentration of bromine, and over six times more effective than an equivalent concentration of iodine. Iodine is commonly used for portable water purification, and bromine is common as a swimming pool disinfectant.

Portable water purification

Portable water purification devices and methods are available for disinfection and treatment in emergencies or in remote locations. Disinfection is the primary goal, since aesthetic considerations such as taste, odour, appearance, and trace chemical contamination do not affect the short-term safety of drinking water.

Other water purification techniques

Other popular methods for purifying water, especially for local private supplies are listed below. In some countries some of these methods are also used for large scale municipal supplies. Particularly important are distillation (de-salination of seawater) and reverse osmosis.

1-**Boiling**: Bringing water to its boiling point (about 100 °C or 212 F at sea level), is the oldest and most effective way since it eliminates most microbes causing intestine related diseases,but it cannot remove chemical toxins or impurities. For human health, complete sterilization of water is not required, since the heat resistant microbes are not intestine affecting. The traditional advice of boiling water for ten minutes is mainly for additional safety, since microbes start getting eliminated at temperatures greater than 60 °C (140 °F).. In areas where the water is "hard" (that is, containing significant dissolved calcium salts), boiling decomposes the bicarbonate ions, resulting in partial precipitation as calcium carbonate. This is the "fur" that builds up on kettle elements, etc., in hard water areas.

2-**Granular Activated Carbon adsorption:** a form of activated carbon with a high surface area, adsorbs many compounds including many toxic compounds. Water passing through activated carbon is commonly used in municipal regions with organic contamination, taste or odors. Many household water filters and fish tanks use activated carbon filters to further purify the water. Household filters for drinking water sometimes contain silver as metallic silver nanoparticle. If water is held in the carbon block for longer periods, microorganisms can grow inside which results in fouling and contamination. Silver nanoparticles are excellent anti-bacterial material and they can decompose toxic halo-organic compounds such as pesticides into non-toxic organic products. . In general, these home filters remove over 90% of the chlorine available to a glass of treated water. These filters must be periodically replaced otherwise the bacterial content of the water may actually increase due to the growth of bacteria within the filter unit.

3-**Distillation** involves boiling the water to produce water vapour. The vapour contacts a cool surface where it condenses as a liquid. Because the solutes are not normally vaporised, they remain in the boiling solution. Even distillation does not completely purify water, because of contaminants with similar boiling points and droplets of unvapourised liquid carried with the steam. However, 99.9% pure water can be obtained by distillation.

4-**Reverse osmosis**: Mechanical pressure is applied to an impure solution to force pure water through a semi-permeable membrane. Reverse osmosis is theoretically the most thorough method of large scale water purification available, although perfect semi-permeable membranes are difficult to create. Unless membranes are well-maintained, algae and other life forms can colonize the membranes.