كلية العلـــوم

FACULTY OF SCIENCE
BENHA UNIVERSITY

Research About

Water Treatment

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2		
3		
4		

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Table of content

• Introduction:

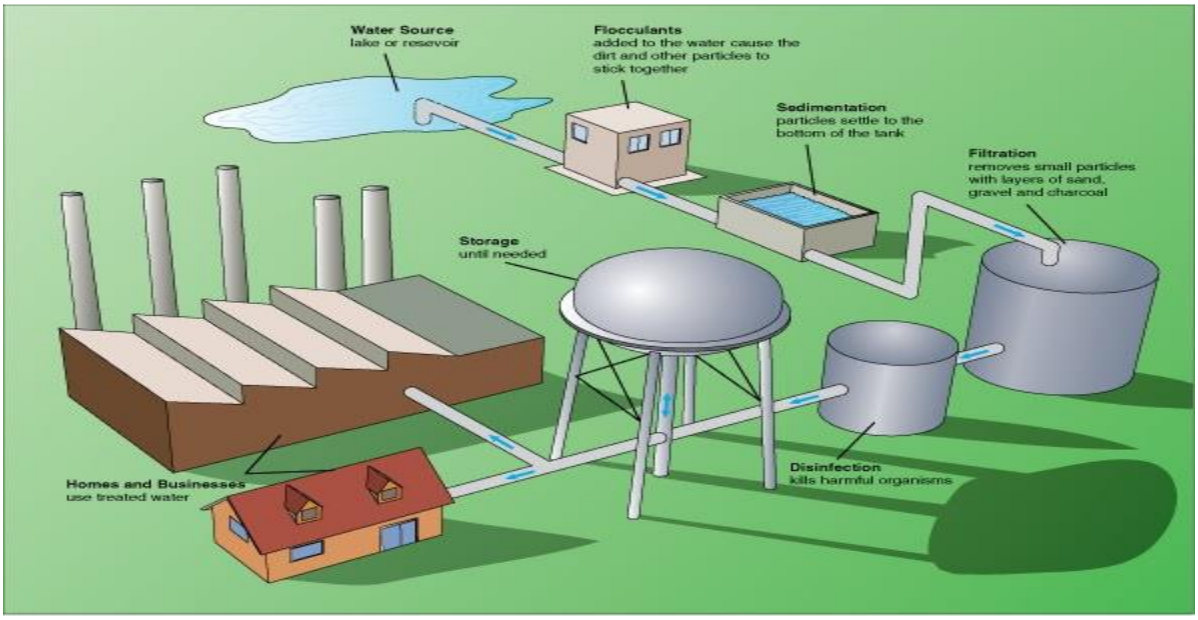
Water treatment is any process that improves the quality of water to make it appropriate for a specific end-use. The end use may be drinking, industrial water supply, irrigation, river flow maintenance, water recreation or many other uses, including being safely returned to the environment. Water treatment removes contaminants and undesirable components or reduces their concentration so that the water becomes fit for its desired end-use. This treatment is crucial to human health and allows humans to benefit from both drinking and irrigation use.

Water treatment and water technologies are an essential line of defence to remove contaminants and bacteria before the delivery of clean, portable water supplies for consumption. Water sources can be subject to contamination and therefore require appropriate treatment to remove disease-causing agents. Public drinking water systems use a variety of methods to provide safe drinking water for their communities. Depending on the continent, country and region, different water treatment systems may be in operation depending on regional regulations and raw water input.

Drinking water treatment:

Water contamination is primarily caused by the discharge of untreated wastewater from enterprises. The effluent from various enterprises, which contains varying levels of contaminants, is dumped into rivers or other water resources. The wastewater may have a high proportion of organic and inorganic contaminants at the initial discharge. Industries generate wastewater because of fabrication processes, processes dealing with paper and pulp, textiles, chemicals, and from various streams such as cooling towers, boilers, and production lines. Typical drinking water treatment processes.

Treatment for drinking water production involves the removal of contaminants and/or inactivation of any potentially harmful microbes from raw water to produce water that is pure enough for human consumption without any short term or long-term risk of any adverse health effect. In general terms, the greatest microbial risks are associated with ingestion of water that is contaminated with human or animal (including bird) feces. Feces can be a source of pathogenic bacteria, viruses, protozoa and helminths. The removal or destruction of microbial pathogens is essential, and commonly involves the use of reactive chemical agents such as suspended solids, to remove bacteria, algae, viruses, fungi, and minerals including iron and manganese. Research including Professor Linda Lawton's group at Robert Gordon University, Aberdeen is working to improve detection of cyanobacteria. These substances continue to cause great harm to several less developed countries who do not have access to effective water purification systems. Measures taken to ensure water quality not only relate to the treatment of the water, but to its conveyance and distribution after treatment. It is therefore common practice to keep residual disinfectants in the treated water to kill bacteriological contamination during distribution and to keep the pipes clean. Water supplied to domestic properties such as for tap water or other uses, may be further treated before use, often using an in-line treatment process. Such treatments can include water softening or ion exchange.



"Illustration of a typical drinking water treatment process"

A- <u>Wastewater treatment:</u>

Wastewater treatment is a process which removes and eliminates contaminants from wastewater. It thus converts it into an effluent that can be returned to the water cycle. Once back in the water cycle, the effluent creates an acceptable impact on the environment. It is also possible to reuse it. This process is called water reclamation. The treatment process takes place in a wastewater treatment plant. There are several kinds of wastewater which are treated at the appropriate type of wastewater treatment plant. For domestic wastewater the treatment plant is called a Sewage Treatment. Municipal wastewater or sewage are other names for domestic wastewater. For industrial wastewater, treatment takes place in a separate Industrial wastewater treatment, or in a sewage treatment plant. In the latter case it usually follows pre-treatment. Further types of wastewater treatment plants include Agricultural wastewater treatment and leachate treatment plants. One common process in wastewater treatment is phase separation, such as sedimentation. Biological and chemical processes such as oxidation are another example. Polishing is also an example. The main by-product from wastewater treatment plants is a type of sludge that is usually treated in the same or another wastewater treatment plant. Biogas can be another by-product if the process uses anaerobic treatment. Treated wastewater can be reused as reclaimed water. The main purpose of wastewater treatment is for the treated wastewater to be able to be disposed or reused safely. However, before it is treated, the options for disposal or reuse must be considered so the correct treatment process is used on the wastewater. The term "wastewater treatment" is often used to mean "sewage treatment".

“La Crosse wastewater treatment facility”

Processes:

For the elimination of hazardous chemicals from the water, many treatment procedures have been applied.

The processes involved in removing the contaminants include physical processes such as settling and filtration, chemical processes such as disinfection and coagulation, and biological processes such as slow sand filtration. A combination selected from the following processes (depending on the season and contaminants and chemicals present in the raw water) is used for municipal drinking water treatment worldwide.

1- Chemical:

Different chemical procedures for the conversion into final products or the removal of pollutants are used for the safe disposal of contaminants.

- Pre-chlorination for algae control and arresting biological growth.
- Aeration along with pre-chlorination for removal of dissolved iron when present with relatively small amounts of manganese.
- Disinfection for killing bacteria, viruses and other pathogens, using chlorine, ozone and ultra-violet light.

2- Physical:

Physical techniques of water/wastewater treatment rely on physical phenomena to complete the removal process, rather than biological or chemical changes. Most common physical techniques are:

- Sedimentation is one of the most important main wastewater treatment procedures. Gravity settling is a method of separating particles from a fluid. The particle in suspension remains stable in quiescent conditions due to the decrease in water velocity throughout the water treatment process, following which the particles settle by gravitational force. For solids separation that is the removal of suspended solids trapped in the floc.

- Filtration is the technique of removing pollutants based on their particle size. Pollutant removal from wastewater permits water to be reused for a variety of purposes. The types of filters used in the procedure differ depending on the contaminants present in the water. Particle filtration and Membrane filtration are the two main forms of wastewater filtration.
- Dissolved air flotation (Degasification) is the process of removing dissolved gases from a solution. Henry's law states that the amount of dissolved gas in a liquid is proportionate to the partial pressure of the gas. Degasification is a low-cost method of removing carbon dioxide gas from wastewater that raises the pH of the water by removing the gas.
- Deaerator is used to reduce oxygen and nitrogen in boiler feed water applications.

“Tanks with sand filters to remove precipitated iron (not working at the time)”

3-Physico-chemical:

Also referred to as "Conventional" Treatment,

- Coagulation for flocculation. The addition of coagulants destabilizes colloidal suspensions by neutralizing their charges, resulting in the aggregation of smaller particles during the coagulation process.
- Coagulant aids, also known as polyelectrolytes – to improve coagulation and for more robust floc formation.
- Polyelectrolytes or also known in the field as polymers, usually consist of either a positive or negative charge. The nature of the polyelectrolyte used is purely based on the source water characteristics of the treatment plant.
- These will usually be used in conjunction with a primary coagulant such as ferric chloride, ferric sulfate, or alum.

Chemical precipitation is a common process used to reduce heavy metals concentrations in wastewater. The dissolved metal ions are transformed to an insoluble phase by a chemical interaction with a precipitant agent such as lime. In industrial applications stronger alkalis may be used to effect complete precipitation. In drinking water treatment, the common-ion effect is often used to help reduce water hardness.

Flotation uses bubble attachment to separate solids or dispersed liquids from a liquid phase.

- **Membrane filtration:**

Membrane filtration can remove suspended solids and organic components, and inorganic pollutants such heavy metals. For heavy metal removal, several forms of membrane filtration, such as ultrafiltration, nanofiltration, and reverse osmosis, can be used depending on the particle size that can be maintained. Amino phosphonates can be added for antiscalant properties to maintain filtration.

- **Ion exchange:**

Ion exchange is a reversible ion exchange process in which an insoluble substance (resin) takes ions from an electrolytic solution and releases additional ions of the same charge in a chemically comparable amount without changing the resin's structure.

- **Electrochemical treatment techniques:**

- Electrodialysis (ED)
- Membrane electrolysis (ME)
- Electrochemical precipitation (EP)

- **Adsorption:**

Adsorption is a mass transfer process in which a substance is transported from the liquid phase to the surface of a solid/liquid (adsorbent) and becomes physically and chemically bonded (adsorbate). Adsorption can be classified into two forms based on the type of attraction between the adsorbate and the adsorbent: physical and chemical adsorption, commonly known as physisorption and chemisorption.

- **Activated carbon:**

Activated carbons (ACs) or biological-activated carbon (BAC) are effective adsorbents for a wide variety of contaminants. The adsorptive removal of color, aroma, taste, and other harmful organics and inorganics from drinking water and wastewater is one of their industrial applications.

Both a high surface area and a large pore size can improve the efficiency of activated carbon. Activated carbon was utilized by several studies to remove heavy metals and other types of contaminants from wastewater. The cost of activated carbon is rising due to a shortage of commercial activated carbon (AC). Because of its high surface area, porosity, and flexibility, activated carbon has a lot of potential in wastewater treatment.

4- Biological:

This is the method by which dissolved and suspended organic chemical components are eliminated through biodegradation, in which an optimal amount of microorganism is given to re-enact the same natural self-purification process. Through two distinct biological process, such as biological oxidation and biosynthesis, microorganisms can degrade organic materials in wastewater. Microorganisms involved in wastewater treatment produce end products such as minerals, carbon dioxide, and ammonia during the biological oxidation process. The minerals (products) remained in the wastewater and were discharged with the effluent. Microorganisms use organic materials in wastewater to generate new microbial cells with dense biomass that is eliminated by sedimentation throughout the biosynthesis process.

- **Developing countries:**

Appropriate technology options in water treatment include both community-scale and household-scale point-of-use (POU) or self-supply designs. Such designs may employ solar water disinfection methods, using solar irradiation to inactivate harmful waterborne microorganisms directly, mainly by the UV-A component of the solar spectrum, or indirectly through the presence of an oxide photocatalyst, typically supported TiO_2 in its anatase or rutile phases. Despite progress in SODIS technology, military surplus water treatment units like the ERDLator are still frequently used in developing countries. Newer military style Reverse Osmosis Water Purification Units (ROWPU) are portable, self-contained water treatment plants are becoming more available for public use.

For waterborne disease reduction to last, water treatment programs that research and development groups start in developing countries must be sustainable by the citizens of those countries. This can ensure the efficiency of such programs after the departure of the research team, as monitoring is difficult because of the remoteness of many locations.

Energy Consumption: Water treatment plants can be significant consumers of energy. In California, more than 4% of the state's electricity consumption goes towards transporting moderate quality water over long distances, treating that water to a high standard. In areas with high quality water sources which flow by gravity to the point of consumption, costs will be much lower. Much of the energy requirements are in pumping. Processes that avoid the need for pumping tend to have overall low energy demands. Those water treatment technologies that have very low energy requirements including trickling filters, slow sand filters, gravity aqueducts.

A 2021 study found that a large-scale water chlorination program in urban areas of Mexico massively reduced childhood diarrheal disease mortality rates.

- **Materials:**

Stainless steels, such as Type 304L and 316L, are used extensively in the fabrication of water treatment plants due to their corrosion resistance to water and to the corrosivity of chlorination used for disinfection.

B- Raw water:

Raw water is water found in the environment that has not been treated and does not have any of its minerals, ions, particles, bacteria, or parasites removed. Raw water includes rainwater, ground water, water from infiltration wells, and water from bodies like lakes and rivers. Raw water is generally unsafe for human consumption due to the presence of contaminants. A major health problem in some developing countries is use of raw water for drinking and cooking. Without treatment, raw water can be used for irrigation, construction, or cleaning purposes. Farmers use it for watering their crops and give it to livestock to drink, storing it in man-made lakes or reservoirs for long periods of time. Construction industries can use raw water for making cement or for damping down unsealed roads to prevent dust rising. Raw water can also be used for flushing toilets and washing cars, as well as any other purposes that do not require it to be consumed by humans. Water in this form is considered raw, as opposed to water which has been treated before consumption, such as drinking water or water which has been used in an industrial process, such as wastewater. Raw water flushing is a method of water conservation where raw water is used for flush toilets.

- **Composition:**

The composition of raw water is naturally variable, but commonly contains one or more of the following significant contaminants, in the form of dissolved ions, particles and living organisms:

- Humic acid and other complex acids, produced by plant decay. These occur in peat and soil and may cause discoloration and metallic taste of water.

- Minerals which make water hard. Most common are carbonates of calcium and magnesium.
- Particles of clay and silt.
- Pathogenic bacteria, viruses, protozoa and their cysts. (waterborne diseases)
- Salt, which makes water brackish, having more salinity than fresh water, but not as much as seawater.

Other, less common, contaminants of raw water include:

- Natural radioactive particles.
- Perfluorinated alkyl acids, such as perfluorooctanoic acid, which are group of pollutants that have been found in wastewater throughout Europe. There are concerns these chemicals could contaminate raw water sources that are commonly used for drinking water.
- Endocrine disruptor compounds: chemicals that can interfere with the endocrine system causing cancerous tumors, birth defects, and other developmental disorders.

These contaminants can be harmful to humans if they drink raw water containing them, or if the water is not treated properly before consumption. The contaminants can also influence the local ecosystem. For example, endocrine disrupting chemicals can have harmful effects on fish populations living in natural lakes and rivers. These growing health concerns have led to the development of guidelines, such HACCP (Hazard Analysis and Critical Control Points), to produce safe drinking water from wastewater and raw water, and research into sustainable water supply alternatives.

- **Treatment:**

Raw water can be used for many purposes, such as cooling water, water for rinsing and chemical production, purified water, and drinking water. However, due to the possible contaminants, raw water must be treated before it is allowed for human consumption or industrial use. There are several steps involved in the treatment of raw water, and different methods in which it can take place.

1- Reverse osmosis:

Reverse osmosis has been used to produce demineralized water for over 30 years. In reverse osmosis, water is transported across a membrane under high pressure, leaving a product that consists mainly of water and a concentrate containing most other components such as minerals and unwanted residues. Many contaminants, including iron, manganese, ammonium, traces of pesticides and medicines, organic micro pollutants, and radioactive particles can be removed with reverse osmosis alone. This efficiency has made reverse osmosis the primary method of water purification, often being used in combination with other methods, as a final treatment. A downside to reverse osmosis is that the removing of most minerals from water can have negative effects on its taste. Minerals are sometimes added to drinking water that was already filtered to improve its taste.

2- Conventional pre-treatment:

The conventional treatment method for water purification is a complex, multistage process that was used for many years. It generally consists of five primary steps. First, raw water is adjusted for alkalinity and pH with the addition of hydrated lime and carbon dioxide. Second, particulate matter is congregated with aluminum sulphate and other coagulants, such as polymers, which the water flows in a cascade that mixes the chemicals and raw water with the coagulants. Third, the water is slowly mixed in clarifiers where larger particles settle down to the bottom and are periodically removed (sedimentation). Fourth, water is directed from the clarifiers to the filters (e.g. anthracite and sand filter) to entrap any smaller particles that survived the clarification process. Finally, sodium hydroxide is added to adjust the final pH/alkalinity, sodiumhypochlorite for disinfection and fluoride for flu oridation. This process is often used as a pre-treatment method while another processes, such as reverse osmosis, is used for the final treatment. A disadvantage of this method is its use of chemicals, such as ozone, flocculants, hydrogen peroxide, lime, and chlorine for the filtration process. These chemicals could be dangerous if used incorrectly or if they remained in the water after complete treatment.

This requires special precautions, and each step of the process must be controlled to achieve an overall optimal performance. The need for a complex control system for conventional treatment can result in it being financially costly. This has led to the development of alternative pre-treatment and treatment methods for raw water.

3- Ultrafiltration:

Ultrafiltration is a membrane filtration process and provides an alternative to conventional pre-treatment. In this method water is only pre-filtered with a common screen filter before being filtered at high pressure through a membrane, separating the water from contaminants within it. Ultrafiltration can be used on its own for water purification or as a pre-treatment for reverse osmosis. Its advantages over conventional pre-treatment include very high-water quality independent of the contaminants in the initial raw water, a plant that is simpler in design and more flexible, which makes it easier to automate, lower use of chemicals, and final product free of viruses and microorganisms.

"Drinking water treatment of 300 m^3/h using ultrafiltration in Grundmühle waterworks (Germany)"

4- Biofilm pre-treatment and bio-diatomite dynamic membrane reactor:

The biofilm membrane filtration method is used to remove harmful chemical by-products, such as NH4+-N, total nitrogen, and dissolved organic matter, that could form from disinfection processes. Biofilm Pre-treatment is a necessary step for water treatment in many parts of world due to its low operation cost and effectiveness at pollutant removal. In this process microorganisms remove contaminants in raw and wastewater that are harmful to humans, but nutrients to them. Bio-diatomite dynamic membrane reactor filtration combines dynamic membrane technology for wastewater treatment, and microbial colonies that form diatomite particles to purify water. These methods are under development in China as part of addressing the country's pollution problems.

- **Turbidity:**

Turbidity is how murky or hazy water seems due to suspended particles. The more suspended particles, the higher the turbidity. Turbidity is used to visually measure water quality, being most common in unfiltered raw water. High amounts of turbidity in raw water can occur due to:

- Increased flow due to heavy rain fall
- Spring turnover of water masses
- Bank erosion
- Sediment resuspension in shallow areas

- Temporary increase from the more turbid areas

- **Turbidity and health concerns:**

During high turbidity peaks, pathogens are more commonly found in raw water. This can contribute to the spread of illnesses. When turbidity increases, reported hospital visits for the elderly (65+) with gastrointestinal illnesses also increase. Even places with water filtration systems that meet standards can have an endemic of gastrointestinal illness, or waterborne infectious diseases. Those hospitalized represent a small percentage of total morbidity caused by these illnesses.

- **Controlling turbidity:**

Controlling the land surrounding raw water reservoirs and other sources is key to reducing turbidity. Areas of high sediment resuspension and erosion need attending regularly, and screens and other devices are needed to catch suspended particles. Screens that trap particles and debris must be cleaned consistently. Flushing out water pumps should be done when demand is lowest. This gives time for the water to settle and decrease turbidity before is it needed in high amounts. "Turbidity reduction is best achieved when the water is run through a series of chemical and physical treatment methods before reaching the filter".

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Thank You