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OPEN AND DISTANCE LEARNING (ODL) PROGRAMMES

(FOR THOSE WHO JOINED THE PROGRAMMES FROM THE ACADEMIC YEAR 2023–2024)

M.Sc. Physics

Course Material

SEWAGE AND WASTE WATER TREATMENT AND REUSE

SPHE22

Prepared

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Tirunelveli - 12

SEWAGE AND WASTE WATER TREATMENT AND REUSE

SPHE22

UNITS	DETAILS
I	**RECOVERY & REUSE OF WATER:** Recovery & Reuse of water from Sewage and Waste water: Methods of recovery: Flocculation - Sedimentation - sedimentation with coagulation - Filtration - sand filters - pressure filters - horizontal filters - vector control measures in industries-chemical and biological methods of vector eradication.
II	**DISINFECTION:** Introduction to disinfection and sterilization: Disinfectant -UV radiation - Chlorination - Antisepsis - Sterilant - Aseptic and sterile - Bacteriostatic and Bactericidal - factors affecting disinfection.
III	**CHEMICAL DISINFECTION:** Introduction - Theory of Chemical Disinfection - Chlorination Other Chemical Methods - Chemical Disinfection Treatments Requiring - Electricity - Coagulation/Flocculation Agents as Pretreatment - Disinfection By-Products (DBPs)
IV	**PHYSICAL DISINFECTION:** Introduction - Ultraviolet Radiation - Solar Disinfection - Heat Treatment - Filtration Methods -Distillation - Electro chemical Oxidation Water Disinfection by Microwave Heating.
Recommended Text	
1	Drinking water and disinfection technique, Anirudhha Balachandra. CRC press (2013)
2	Design of Water and Wastewater Treatment Systems (CV-424/434), Shashi Bushan,(2015) Jain Bros
3	Integrated Water Resources Management, Sarbhukan MM,CBS PUBLICATION (2013)
4	C.S.Rao, Environmental Pollution Control Engineering, New Age International, 2007
5	S.P. Mahajan, Pollution control in process industries, 27th Ed. Tata McGraw Hill Publishing Company Ltd., 2012.

UNIT - I

RECOVERY & REUSE OF WATER

Recovery & Reuse of water from Sewage and Waste water:

The growing global demand for freshwater, coupled with depleting water sources and environmental degradation, underscores the critical need for innovative water management solutions. One such solution gaining traction is the recovery and reuse of water from sewage and wastewater. Traditionally, sewage and wastewater have been viewed as liabilities, associated with pollution and health hazards. However, advancements in technology and shifting perspectives have transformed these once discarded resources into valuable assets. Through processes like advanced filtration, reverse osmosis, and UV disinfection, it's now possible to treat sewage and wastewater to meet various quality standards suitable for reuse. This treated water, often termed reclaimed water or recycled water, can serve a myriad of purposes, including irrigation, industrial processes, and even potable water supply after stringent treatment.

The benefits of water recovery and reuse are manifold. Firstly, it reduces the strain on freshwater sources, easing pressure on ecosystems and mitigating water scarcity. Secondly, it minimizes pollution by preventing the discharge of untreated or partially treated wastewater into water bodies, thus safeguarding public health and the environment. Additionally, it offers economic advantages, as reclaimed water is often cheaper than freshwater sources and can reduce the costs associated with wastewater treatment and disposal. Despite its numerous benefits, widespread adoption of water recovery and reuse faces challenges, including regulatory hurdles, public perception, and infrastructure limitations. However, with continued research, investment, and stakeholder collaboration, these challenges can be overcome, paving the way for a more sustainable and resilient water future. In conclusion, the recovery and reuse of water from sewage and wastewater represent a crucial strategy for addressing water scarcity, pollution, and sustainability challenges. By harnessing the potential of these untapped resources, we can build a more resilient and water-secure world for current and future generations.

Methods of recovery:

The common of waste water recovered by the following types

- Flocculation
- Sedimentation
- sedimentation with coagulation
- Filtration
- sand filters
- pressure filters
- horizontal filters

Flocculation

Flocculation is a process in which small particles in a liquid clump together to form larger particles, or flocs. This can be done by adding a flocculant, which is a substance that helps to destabilize the particles and make them more likely to clump together. Flocculation is used in a variety of industries, including water treatment, wastewater treatment, and mining.

Flocculation is an important process in a variety of industries. It is used to remove suspended solids, pollutants, and minerals from liquids. Flocculation is a safe and effective process that can help to improve the quality of water and wastewater.

In water and wastewater treatment, flocculation is used to remove suspended solids from water. This is done by adding a flocculant to the water, which causes the suspended solids to clump together and form flocs. The flocs are then easily removed from the water by sedimentation or filtration.

Flocculants are used in water treatment to help remove suspended solids from water. They do this by binding together small particles into larger flocs, which can then be more easily removed by sedimentation or filtration. Flocculants are typically added to water after coagulation, which is the process of neutralizing the charges on the particles so that they can clump together. The most common flocculants used in water treatment are polyacrylamides, which are synthetic polymers that have a high molecular weight.

Flocculants work in water treatment:

Coagulants are added to water to neutralize the charges on the particles. Flocculants are added to the water to bind together the small particles that have been neutralized by the coagulants. The flocs are then allowed to settle to the bottom of the tank or be filtered out of the water.

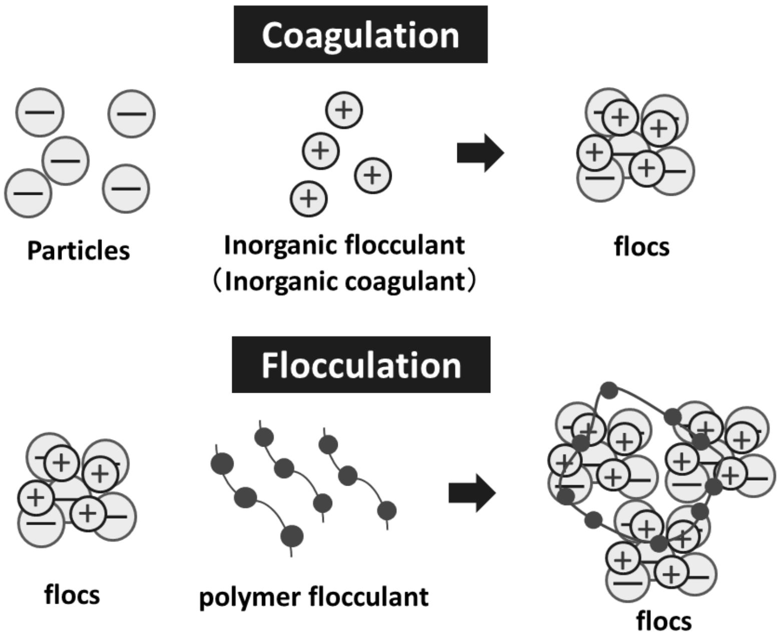

Fig 1.1. Schematic of flocs formation

Flocculation is an important step in water treatment because it helps to remove suspended solids that would otherwise be difficult to remove. This makes the water cleaner and safer to drink. There are a number of different flocculants that can be used, including inorganic flocculants, organic flocculants, and natural flocculants. Inorganic flocculants are typically salts of metal ions, such as aluminum sulfate and ferric chloride. Organic flocculants are typically polymers, such as polyelectrolytes. Natural flocculants are typically plant extracts, such as chitosan. The choice of flocculant depends on the specific application.

For example, inorganic flocculants are typically used in water treatment, while organic flocculants are typically used in wastewater treatment.

Sedimentation

Sedimentation is one of the methods that municipalities use for treating water. It is a physical water treatment process. Gravity is used to remove suspended solids from water as shown in Fig 1.2.

The effectiveness depends on the size and weight of the particles. Suspended solids that have a specific gravity similar to water remain suspended while heavier particles settle. The sedimentation process in wastewater treatment usually occurs in tanks of various shapes.

Sedimentation with coagulation

Sedimentation is the process of allowing particles in suspension in water to settle out of the suspension under the effect of gravity. The particles that settle out from the suspension become sediment, and in water treatment is known as sludge. When a thick layer of sediment continues to settle, this is known as consolidation. When consolidation of sediment, or sludge, is assisted by mechanical means then this is known as thickening.

In water treatment sedimentation might be used to reduce the concentration of particles in suspension before the application of coagulation, to reduce the amount of coagulating chemicals needed, or after coagulation and, possibly, flocculation. When sedimentation is applied after coagulation, its purpose is usually to reduce the concentration of solids in suspension so that the subsequent filtration can function most effectively.

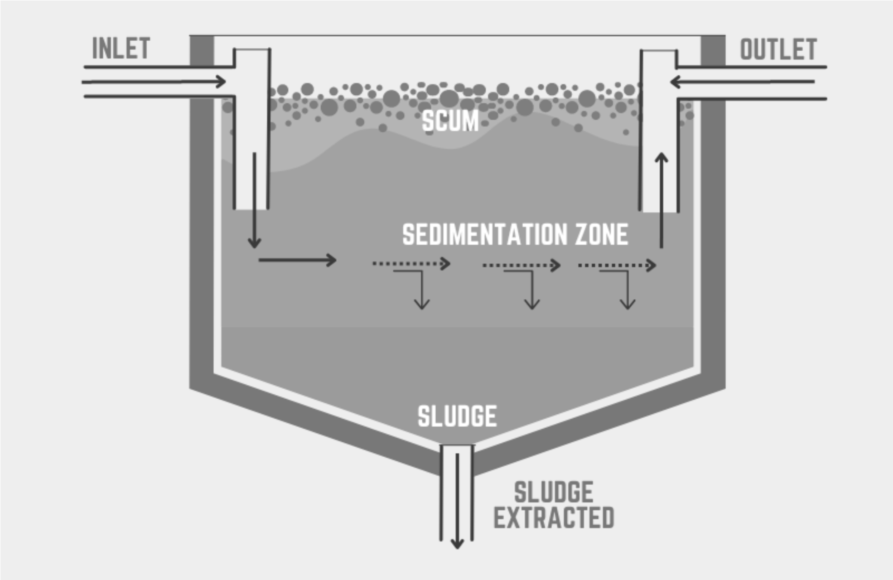

Fig 1.2. Sedimentation tank

Sedimentation is one of several methods for application prior to filtration: other options include dissolved air flotation and some methods of filtration. Generically, such solids-liquid separation processes are sometimes referred to as clarification processes.

There is a variety of methods for applying sedimentation and include: horizontal flow, radial flow, inclined plate, ballasted floc and floc blanket sedimentation.

Filtration

Once the flocs have settled to the bottom of the water, the clear water on top is filtered to separate additional solids from the water. During filtration, the clear water passes through filters that have different pore sizes and are made of different materials (such as sand, gravel, and charcoal). These filters remove dissolved particles and germs, such as dust, chemicals, parasites, bacteria, and viruses. Activated carbon filters also remove any bad odors.

Water treatment plants can use a process called ultrafiltration in addition to or instead of traditional filtration. During ultrafiltration, the water goes through a filter membrane with very small pores. This filter only lets through water and other small molecules (such as salts and tiny, charged molecules).

Reverse osmosis external icon is another filtration method that removes additional particles from water. Water treatment plants often use reverse osmosis when treating recycled water external icon (also called reused water) or salt water for drinking.

Sand filters

Sand filters operate on a simple yet effective principle, making them a cornerstone of water treatment systems worldwide. Consisting of a bed of specially graded sand, these filters utilize physical and chemical mechanisms to purify water. As water flows through the sand bed, suspended particles, colloids, and impurities are trapped within the gaps between sand grains through mechanisms such as straining, adsorption, and sedimentation. The depth and composition of the sand bed are engineered to optimize filtration efficiency, with finer sand typically used near the top for finer filtration and coarser sand deeper down for support and drainage. Over time, as the sand bed accumulates impurities, the filter undergoes backwashing—a process where water is pumped backward through the filter, dislodging trapped particles and restoring filtration capacity. Sand filters are valued for their simplicity, reliability, and versatility, finding applications in municipal water treatment plants, swimming pools, irrigation systems, and decentralized water purification setups.

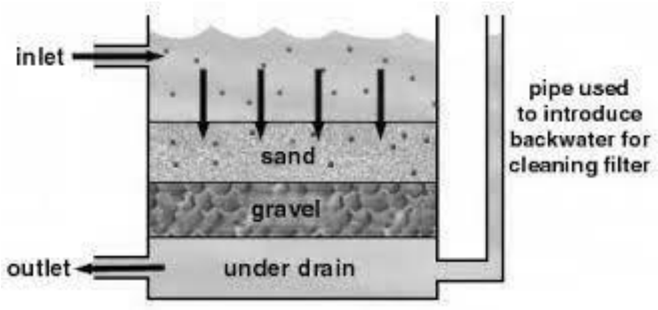

Fig 1.3. Sand filter

Pressure filters

One of the most cost-effective ways to accomplish this is with a pressure filter. Sometimes referred to as "sand filters," a pressure filter consists of a rigid filter vessel capable of withstanding internal pressure, combined with pipework to distribute and collect water and one or multiple types of filter media. Pressure filters are commonly used in municipal water systems, industrial facilities, residential well water systems, and swimming pools. Typical pressure filter construction is shown below:

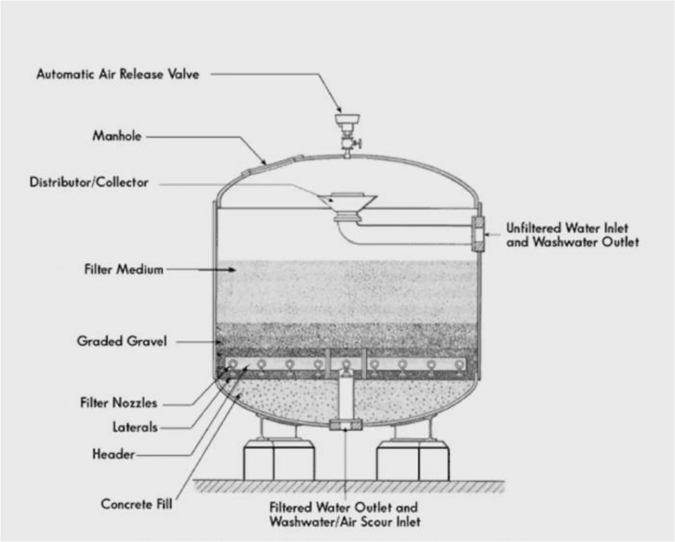

Fig 1.4. Section Through Typical Downflow Pressure Filter

At the top of the filter vessel, a distributor is used to break up and distribute the water flow so that there are no concentrated flow jets that stir up the media bed. Inflow distributors are usually oriented to direct flow at the top of the vessel to disperse the flow further. Below the distributor is the primary filter bed. The filter bed contains fine-grained media, most often sand, including crushed anthracite coal, activated charcoal, garnet, or other granular bulk products. The media bed is the thickest layer in the filter vessel and is the region that does the actual filtering of the water or other fluid. Below the media bed will be one or more support layers. These will usually be larger-sized gravel that is chosen to support the filter bed while allowing high flow through the support layer and into the outflow header. The outflow header can take several forms but is often composed of a large central pipe with multiple smaller pipes or "laterals" attached. The laterals are slotted or perforated. This allows the pressurized water to flow into the laterals and out through the outflow header into the downstream components of the water treatment system.

Horizontal filters

A horizontal filter, also known as a horizontal flow filter, is a type of water treatment system designed to remove impurities and contaminants from water using a horizontal filtration process shown in Fig 1.5. In this system, water flows horizontally through a filter media bed, typically consisting of materials like sand, anthracite, or activated carbon. As water passes through the filter bed, suspended solids, sediment, and other impurities are trapped within the media, resulting in cleaner water on the other side. Horizontal filters are often used in applications where space is limited, as they require less vertical height compared to vertical filters. They are commonly employed in small to medium-sized water treatment facilities, swimming pools, and decentralized water purification systems. Horizontal filters offer efficient filtration, easy maintenance, and can be customized with different media types to target specific contaminants, making them versatile solutions for various water treatment needs.

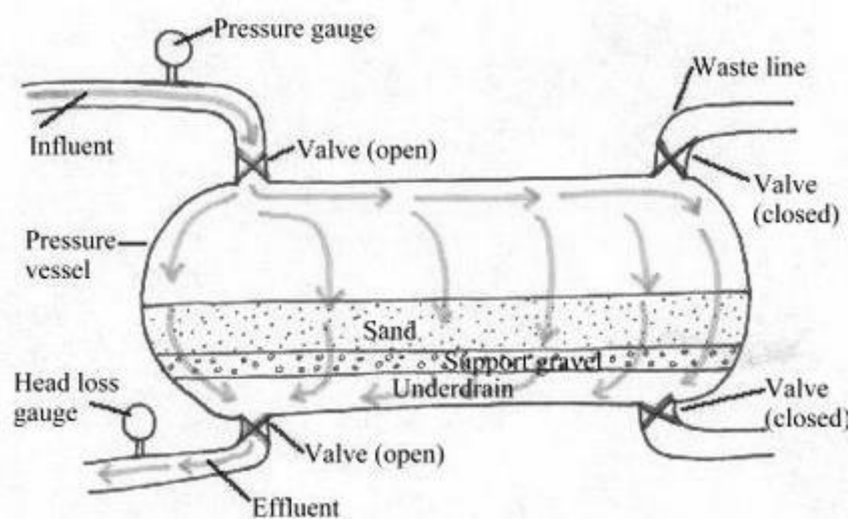

Fig 1.5. Horizontal filters

Vector control measures in industries

Vector control measures in industries are essential for maintaining a safe and healthy working environment and preventing the spread of vector-borne diseases. Here are some common vector control measures implemented in industries:

Sanitation Practices:

Regular cleaning and proper waste management are crucial for eliminating breeding sites for vectors such as mosquitoes, flies, and rodents. This includes cleaning up spills promptly, properly storing and disposing of waste, and maintaining a clean and clutter-free workspace.

Integrated Pest Management (IPM):

IPM involves the use of multiple methods to control pests and vectors, including physical, chemical, biological, and cultural controls. This approach minimizes reliance on chemical pesticides and focuses on preventive measures such as sealing entry points, using traps, and promoting natural predators of pests.

Vegetation Management:

Keeping vegetation around industrial sites trimmed and well-maintained can help reduce harbourage areas for vectors like mosquitoes and rodents, minimizing their presence and breeding opportunities.

Water Management:

Proper management of water sources within industrial facilities is critical for preventing the breeding of mosquitoes and other waterborne vectors. This includes regularly inspecting and maintaining drainage systems, eliminating standing water, and treating water bodies that cannot be drained.

Personal Protective Equipment (PPE):

Providing employees with appropriate PPE, such as long-sleeved clothing, gloves, and insect repellent, can help reduce their exposure to vectors and minimize the risk of vector-borne diseases.

Training and Education:

Educating employees about vector-borne diseases, their transmission, and preventive measures is essential for raising awareness and promoting compliance with control measures. Training programs can also include instruction on proper sanitation practices and the identification of potential vector breeding sites.

Monitoring and Surveillance:

Regular monitoring of vector populations and surveillance for signs of vector-borne diseases can help detect problems early and implement appropriate control measures promptly. This may involve conducting inspections, setting up traps, and monitoring environmental conditions conducive to vector breeding.

Chemical and biological methods of vector eradication.

Chemical Methods:

Insecticides: Chemical insecticides are commonly used to control vector populations. They can be applied through various methods such as spraying, fogging, or treating breeding sites. Insecticides target specific stages of the vector's life cycle, disrupting their development or killing them directly. Examples include pyrethroids, organophosphates, and larvicides like Methoprene.

Space Spraying: This method involves the application of insecticides in the form of aerosols or fog to target adult mosquitoes or flies in the air. It's often used in outdoor settings to reduce adult vector populations quickly and is effective for immediate control during disease outbreaks or in high-risk areas.

Residual Spraying: Residual insecticides are applied to surfaces where vectors rest or harbour, such as walls, ceilings, and vegetation. These insecticides remain active for an extended period, providing continuous control of vectors. Indoor residual spraying is commonly used for mosquito control in areas where insecticide-resistant mosquitoes are present or where other control measures are ineffective.

Biological Methods:

Biological Control Agents: Biological control involves the use of natural enemies or pathogens to suppress vector populations. Examples include using predatory insects like dragonflies or introducing microbial agents such as Bacillus thuringiensis israelensis, which targets mosquito larvae. These methods are often more environmentally friendly and sustainable compared to chemical control but may require more time to establish effective control.

Sterile Insect Technique (SIT): SIT involves releasing sterile male insects into the wild to mate with wild females. Since no offspring result from these mating’s, the overall population declines over time. SIT has been used successfully to control mosquitoes, fruit flies, and other pests but requires careful coordination and large-scale implementation to be effective.

Genetic Control: Genetic control methods aim to modify the genetics of vector populations to reduce their ability to transmit diseases or to suppress their populations. Techniques like gene editing and gene drive technology are being explored for vector control, but ethical and regulatory concerns need to be addressed before widespread implementation.

UNIT - II

DISINFECTION

Introduction to disinfection and sterilization:

Disinfection and sterilization are critical processes used to eliminate or reduce the microbial load on surfaces, instruments, and environments to prevent the transmission of infectious diseases. While both aim to kill or inactivate microorganisms, they differ in their objectives and effectiveness against various pathogens.

Disinfection:

Disinfection involves the use of chemical or physical agents to reduce the number of viable microorganisms on surfaces and objects to a level that is considered safe for public health. Disinfectants target a broad spectrum of microorganisms, including bacteria, viruses, and fungi, but may not necessarily eliminate all microbial forms, such as bacterial spores. Disinfection is commonly used in healthcare settings, food processing facilities, and household environments to prevent the spread of infectious pathogens.

Sterilization:

Sterilization, on the other hand, is a more rigorous process that aims to completely eradicate all forms of microbial life, including bacteria, viruses, fungi, and bacterial spores. Sterilization methods typically involve heat, chemicals, radiation, or a combination of these approaches to achieve complete microbial destruction. Sterilization is essential for critical medical instruments, surgical equipment, and pharmaceutical products that must be free from any viable microorganisms to prevent infections in patients.

Disinfectant

A disinfectant is a chemical agent, which destroys or inhibits growth of pathogenic microorganisms in the non-sporing or vegetative state. Disinfectants do not necessarily kill all organisms but reduce them to a level, which does not harm health or the quality of perishable goods. Disinfectants are applied to inanimate objects and materials such as instruments and surfaces to control and prevent infection.

UV radiation

Ultraviolet light, or UV, is an effective means to disinfect, or deactivate pathogens. This is accomplished by exposing waterborne microorganisms to ultraviolet light, having a wavelength of 254 nanometres (nm), at a specified intensity for a specified period of time. The UV light damages the genetic materials (DNA) within the organism so that it is incapable of continued growth or reproduction. UV is a safe form of disinfection that does not rely on either chlorine related feed systems or sulfur based dechlorination agents to be applied to the plant effluent flow. UV is effective when effluent turbidities remain low. Unlike chlorine where a residual measurement assumes a level of disinfection, routine bacteriological testing of plant effluent must be performed to assure that the system is operating satisfactorily. Also, UV leaves no residual so there is no protection from recontamination. UV disinfection has become an attractive alternative to chlorination because of its effectiveness, simplicity of operation, ease of installation, and low operating and capital costs. Typical UV lamp configurations are shown in Figure 2.1.

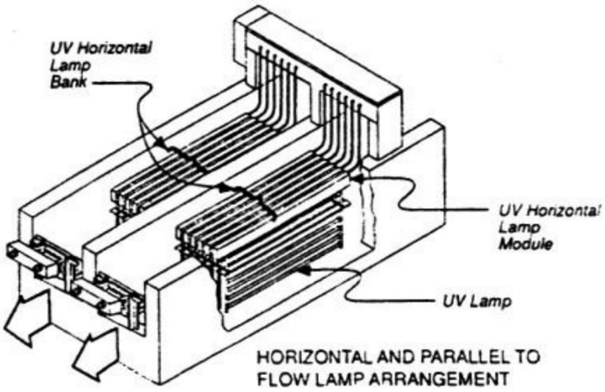

Fig 2.1. UV radiation apparatus

Chlorination

Chlorine and its various forms are powerful oxidants that will kill or inactivate most pathogenic organism that are harmful to human and animal life. Chlorination is the most commonly used disinfection process for wastewater treatment.

Chlorination chemicals are relatively:

➢ Easy to obtain

➢ Economical

➢ Effective

➢ Easy to apply

Typical forms of chlorine used in wastewater treatment are:

➢ Elemental chlorine

➢ Hypochlorite

➢ Chlorine Dioxide

Antisepsis

Antisepsis is the practice of using antimicrobial agents to inhibit or prevent the growth of microorganisms on living tissues, particularly on the skin and mucous membranes, to reduce the risk of infection. Unlike disinfection, which targets inanimate objects and surfaces, antisepsis is specifically focused on preventing microbial colonization and growth on the human body.

Antiseptics are the agents used in antisepsis. They may include chemicals like alcohol, iodine, chlorhexidine, and hydrogen peroxide, as well as natural substances like tea tree oil and honey. Antiseptics work by disrupting the cell membranes of microorganisms or interfering with their metabolic processes, ultimately leading to their destruction or inhibition.

Antisepsis is widely employed in medical settings, including hospitals, clinics, and during surgical procedures, to reduce the risk of surgical site infections and other healthcare-associated infections. It is also used in everyday situations such as wound care and personal hygiene practices to prevent infections and promote healing.

While antiseptics are generally safe for use on intact skin and mucous membranes, their effectiveness can vary depending on factors such as the type of microorganisms present, the concentration and formulation of the antiseptic, and the duration of contact with the target area. It's important to follow recommended guidelines for antiseptic use to ensure optimal efficacy and minimize the risk of adverse effects.

Sterilant

A sterilant is a type of chemical agent or process used to achieve sterilization, which is the complete elimination or destruction of all forms of microbial life, including bacteria, viruses, fungi, and bacterial spores. Unlike disinfectants, which reduce microbial populations to levels considered safe for public health, Sterilant are designed to completely eradicate all viable microorganisms, ensuring that the treated item or surface is entirely free from microbial contamination.

Sterilant are employed in various settings where absolute sterility is essential, such as healthcare facilities, pharmaceutical manufacturing, and food processing industries. Common sterilization methods utilizing sterilant include:

Chemical Sterilization: Chemical sterilant, such as ethylene oxide (ETO), hydrogen peroxide, and peracetic acid, are used to sterilize heat-sensitive medical devices, instruments, and equipment. These agents penetrate the material and effectively kill all microorganisms, including bacterial spores, without causing damage to delicate instruments.

Liquid Chemical Sterilization: Liquid chemical sterilization systems utilize a combination of sterilant and activator solutions to achieve rapid sterilization of heat-sensitive items. Examples include glutaraldehyde-based solutions, which are commonly used for the sterilization of endoscopes and other medical devices.

Gas Sterilization: Gas sterilization methods, such as ethylene oxide (ETO) and ozone gas, are effective for sterilizing heat-sensitive materials and equipment. These gases penetrate packaging materials and complex-shaped objects, ensuring complete microbial eradication.

Plasma Sterilization: Plasma sterilization involves the use of low-temperature plasma to achieve sterilization of medical devices and surgical instruments. Plasma generates highly reactive species that destroy microbial cells, making it suitable for heat-sensitive materials.

Sterilant play a critical role in ensuring patient safety, preventing the spread of infections, and maintaining the sterility of medical and pharmaceutical products. However, it's essential to use sterilant in accordance with established guidelines and protocols to ensure efficacy and safety. Improper use or exposure to sterilant can pose health risks and may result in adverse effects.

Aseptic and sterile

Sterilization

According to the CDC, sterilization is “the use of a physical or chemical procedure to destroy all microorganisms, including large numbers of resistant bacterial spores.” [https://www.cdc.gov/oralhealth/infectioncontrol/glossary.htm#S] With this in mind, a truly sterile environment requires the complete elimination and therefore, absence of any type of microorganism. These organisms include bacteria, fungus, and spores.

Sterilization requires an understanding of the types and sources of contamination and rigorous protocols to avoid and eliminate contamination. Humans are the most common source of contamination in cleanrooms and maintaining sterile conditions. Therefore, in addition to proper cleaning protocols, training, gowning, and other cleanroom best practices are required.

Aseptic

An aseptic process is still related to microorganisms; however, this is about creating and maintaining a specific state of sterility. This does not eliminate all microorganisms. Instead, it is about eliminating contamination from unwanted microorganisms and ensuring none will be introduced into the sample. Asepsis is the prevention of contamination from microorganisms in the cleanroom and on tissues and materials to maintain the state that was achieved through killing, removing, or excluding specific organisms.

Bacteriostatic and Bactericidal

Bacteriostatic: Substances that are bacteriostatic inhibit the growth and reproduction of bacteria without necessarily killing them. This means that while they prevent bacteria from multiplying, they don't directly eliminate them. Bacteriostatic agents essentially put bacteria in a dormant state, allowing the body's immune system to eventually clear the infection.

Example: Tetracycline is a broad-spectrum antibiotic that inhibits bacterial protein synthesis. It is commonly used to treat a variety of bacterial infections, such as respiratory tract infections, urinary tract infections, and acne.

Bactericidal: On the other hand, bactericidal substances directly kill bacteria. They not only inhibit bacterial growth but also lead to the death of the bacteria. Bactericidal agents are often more potent in rapidly reducing the bacterial load in an infection compared to bacteriostatic agents.

Example: Penicillin is one of the oldest and most widely used antibiotics. It works by interfering with the synthesis of bacterial cell walls, leading to the death of susceptible bacteria. Penicillin is used to treat a variety of bacterial infections, including streptococcal infections, pneumococcal infections, and syphilis.

Factors affecting disinfection.

Several factors can influence the effectiveness of disinfection. Some of the common factors are:

- Type of Microorganism
- Concentration of Disinfectant
- Contact Time
- pH and Temperature
- Organic Matter
- Surface Type
- Presence of Biofilms
- Exposure to Light
- Microbial Resistance

Type of Microorganism: Different disinfectants may have varying effectiveness against different types of microorganisms. For example, some disinfectants may be more effective against bacteria than viruses or fungi, while others may be effective against a broader spectrum of microorganisms.

Concentration of Disinfectant: The concentration of the disinfectant solution is crucial. Higher concentrations often result in more effective disinfection, but it's essential to follow manufacturer recommendations to avoid potential harm to surfaces or individuals.

Contact Time: The duration for which the disinfectant is in contact with the surface or the microorganisms is vital. Most disinfectants require a certain contact time to effectively kill or inactivate the microorganisms present. Insufficient contact time may reduce effectiveness.

pH and Temperature: pH levels and temperature can impact the effectiveness of disinfectants. Some disinfectants may work better in certain pH ranges, and temperature variations can influence the rate of disinfection.

Organic Matter: Presence of organic matter, such as blood, saliva, or feces, can reduce the effectiveness of disinfectants. Organic matter can interfere with the action of disinfectants by binding to active sites or providing protection for microorganisms.

Surface Type: The type of surface being disinfected can affect the efficacy of the disinfectant. Some surfaces may be more porous or have crevices where microorganisms can hide, making it harder for the disinfectant to reach and kill them.

Presence of Biofilms: Biofilms are communities of microorganisms embedded in a matrix of extracellular polymeric substances. They can form on surfaces and make microorganisms more resistant to disinfection by providing a protective barrier.

Exposure to Light: Some disinfectants may degrade when exposed to light, reducing their effectiveness. It's essential to store disinfectants properly and follow manufacturer recommendations for usage and storage conditions.

Microbial Resistance: Over time, microorganisms may develop resistance to certain disinfectants. It's important to use a variety of disinfectants and rotate them periodically to prevent the development of resistance.

UNIT - III

CHEMICAL DISINFECTION

Introduction

Disinfection may be defined as the process of destruction or inactivation of harmful micro-organism in water either by physical process or chemical process. Physical process includes heating, ultraviolet radiation etc. and chemical process includes addition of disinfectants such as chemicals. Disinfection can be distinguished from sterilization. In sterilization process, all organisms are usually killed by a physical phenomenon such as boiling for a long period whereas in disinfection disease or illness causing micro-organism are reduced to such low levels that no infection or disease results when the water is used for domestic purposes including drinking water. Since the most important requirement of drinking water is that it should be free from any micro-organisms that could transmit disease illness to the user, disinfection is, therefore, the most important water treatment process among treatment process of water. In fact, sedimentation or filtration can be spared of but not the disinfection. Hence, disinfection is an essential minimum treatment requirement for any drinking water and it is the final process in the chain of water purification

Chemical disinfection is a crucial process used to control and eliminate harmful microorganisms from various surfaces, water, and air. It involves the application of chemical agents to destroy or inhibit the growth of bacteria, viruses, fungi, and other pathogens, thereby reducing the risk of infectious diseases. The practice of chemical disinfection has been integral to public health efforts for centuries, with ancient civilizations using natural substances like vinegar, alcohol, and plant extracts for sanitization purposes. Today, modern advancements in chemistry and technology have led to a wide range of chemical disinfectants with diverse modes of action and applications. In settings such as healthcare facilities, food processing plants, public spaces, and wastewater treatment plants, chemical disinfection plays a vital role in preventing the transmission of diseases and maintaining hygienic conditions. Common chemical disinfectants include chlorine compounds, hydrogen peroxide, quaternary ammonium compounds, alcohols, and phenols, each with specific properties and applications.

While chemical disinfection is highly effective in controlling microbial contamination, it is essential to consider factors such as disinfectant concentration, contact time, and compatibility with surfaces or materials. Additionally, the potential for disinfection by-products (DBPs) formation and the emergence of antimicrobial resistance highlight the importance of responsible disinfection practices and continuous research into safer and more sustainable disinfection methods. Overall, chemical disinfection plays a critical role in safeguarding public health and ensuring the cleanliness and safety of our environments. By understanding the principles and applications of chemical disinfection, we can effectively combat infectious diseases and promote health and well-being.

Theory of Chemical Disinfection

The theory of chemical disinfection revolves around the application of various chemical agents to control and eliminate harmful microorganisms from surfaces, water, and air. Chemical disinfectants work through different mechanisms to disrupt the structure and function of microbial cells, ultimately leading to their destruction or inhibition. Common modes of action include damaging the cell membrane, interfering with cellular metabolism, disrupting protein synthesis, or damaging genetic material. The efficacy of chemical disinfection depends on several factors, including the type and concentration of disinfectant, contact time, temperature, pH, and the presence of organic matter. Different disinfectants exhibit varying effectiveness against different types of microorganisms, highlighting the importance of selecting the appropriate disinfectant for specific applications. However, it's crucial to strike a balance between effectiveness and safety, considering factors such as toxicity, environmental impact, and the potential for disinfection by-products formation. Continuous research and development in chemical disinfection aim to improve efficacy, minimize adverse effects, and address emerging challenges such as antimicrobial resistance. Overall, understanding the theory of chemical disinfection is essential for implementing effective disinfection protocols to control the spread of infectious diseases and maintain hygienic conditions in various settings.

Chlorination Other Chemical Methods

Chlorination is one of the most widely used chemical methods for disinfection due to its effectiveness, affordability, and ease of application. It involves the addition of chlorine-based compounds, such as chlorine gas, sodium hypochlorite (bleach), or calcium hypochlorite, to water or wastewater to kill or inactivate microorganisms. Chlorine works by oxidizing cellular components and disrupting essential metabolic processes in microorganisms, leading to their destruction.

Aside from chlorination, several other chemical methods are employed for disinfection in various applications:

Chlorine Dioxide ($ClO2$)

Chlorine dioxide is a powerful oxidizing agent that is highly effective against bacteria, viruses, and protozoa. It works by penetrating microbial cell walls and disrupting cellular function. Chlorine dioxide is often used in water treatment for its ability to penetrate biofilms and control odor and taste issues associated with chlorine.

Ozone ($O3$)

Ozone is a strong oxidizing agent produced by passing oxygen molecules through a high-voltage electric field. It is highly effective in disinfecting water due to its ability to react rapidly with microbial cell walls and organic matter. Ozone leaves no residual taste or odor and is often used in water treatment plants and bottling facilities.

UV Radiation

Ultraviolet (UV) radiation is a non-chemical disinfection method that uses UV light to inactivate microorganisms by damaging their DNA. UV radiation disrupts the genetic material of bacteria, viruses, and other pathogens, preventing them from replicating. UV disinfection is commonly used in water treatment plants, wastewater treatment facilities, and healthcare settings.

Hydrogen Peroxide (H_2O_2)

Hydrogen peroxide is a strong oxidizing agent that can effectively kill a wide range of microorganisms, including bacteria, viruses, and fungi. It works by generating reactive oxygen species that damage microbial cell membranes and proteins. Hydrogen peroxide is often used as a disinfectant in healthcare facilities, food processing plants, and industrial settings.

Quaternary Ammonium Compounds (Quats)

Quaternary ammonium compounds are cationic surfactants with antimicrobial properties. They disrupt microbial cell membranes and inhibit cellular functions, leading to microbial death. Quats are commonly used as disinfectants in surface cleaning products, healthcare facilities, and food processing industries.

Chemical Disinfection Treatments Requiring Electricity

Chemical disinfection treatments that require electricity typically involve the use of electrochemical processes to generate disinfectants or enhance the efficacy of chemical agents. These methods leverage electrical energy to produce reactive species or facilitate chemical reactions that lead to microbial inactivation. Some examples of chemical disinfection treatments requiring electricity include:

Electro chlorination

Electro chlorination involves the electrolysis of a brine solution (sodium chloride or potassium chloride) to produce chlorine gas or hypochlorite ions, which are powerful disinfectants. The electrolysis process occurs within an electrolytic cell equipped with electrodes, where an electric current is passed through the brine solution. Chlorine gas or hypochlorite ions are generated at the anode and can be collected and used for disinfection purposes. Electro chlorination systems are commonly used in water treatment plants, swimming pools, and wastewater treatment facilities to produce chlorine on-site for disinfection.

Electrooxidation

Electrooxidation is a process that uses electricity to generate reactive oxidizing species, such as hydroxyl radicals (•OH), ozone (O_3), and hydrogen peroxide (H_2O_2), for disinfection purposes. Electrooxidation systems typically involve passing an electric current through a solution containing water and electrolytes to induce chemical reactions at the electrode surfaces. These reactions produce reactive species that can effectively oxidize and destroy microorganisms, organic pollutants, and odor-causing compounds. Electrooxidation is utilized in water and wastewater treatment, industrial processes, and air purification systems.

Electrocoagulation

Electrocoagulation is a water treatment process that utilizes electrical energy to destabilize suspended particles, colloids, and dissolved contaminants through the formation of coagulant species. In electrocoagulation systems, metal electrodes are immersed in the water to be treated, and an electric current is applied to induce electrolysis. This leads to the release of metal ions (e.g., aluminum or iron) from the electrodes, which react with water and contaminants to form coagulant species shown in Fig 3.1. These coagulants then adsorb and neutralize pollutants, facilitating their removal by sedimentation or filtration. Electrocoagulation is used for the treatment of drinking water, wastewater, and industrial effluents.

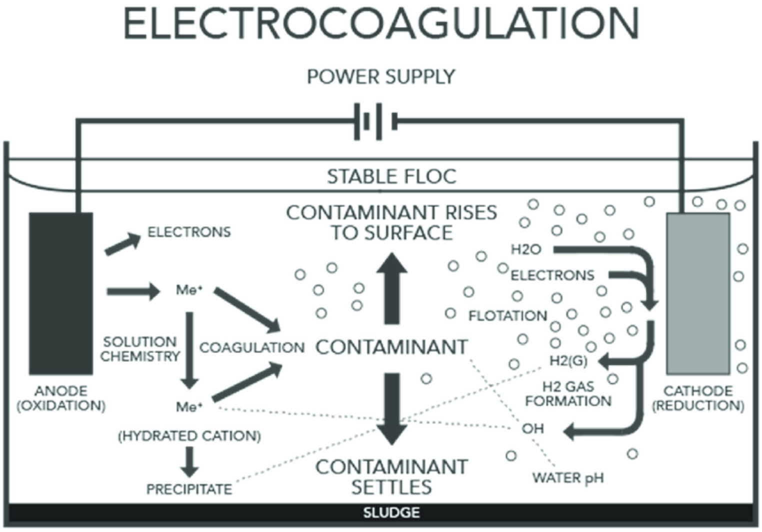

Fig 3.1. Electrocoagulation

Coagulation/Flocculation Agents as Pretreatment

Coagulation and flocculation are common pretreatment processes used in water and wastewater treatment to remove suspended solids, colloidal particles, and organic matter before subsequent treatment steps, such as filtration or disinfection. Coagulation involves the addition of coagulants, which destabilize particles and promote their aggregation, while flocculation involves gentle mixing to encourage the formation of larger flocs that can be more easily removed.

Various chemical agents are employed as coagulants and flocculants in these processes, each with specific properties and applications:

Inorganic Coagulants

Common inorganic coagulants include aluminum sulfate (alum), ferric chloride, and polyaluminum chloride (PAC). These coagulants work by neutralizing the negative charges on suspended particles, promoting their destabilization and aggregation. Inorganic coagulants are effective in removing turbidity, color, and dissolved organic matter from water and wastewater.

Organic Coagulants

Organic coagulants, such as polyDADMAC (polydiallyldimethylammonium chloride) and polyamines, are cationic polymers that adsorb onto particle surfaces and bridge between particles to form larger aggregates. Organic coagulants are particularly effective in treating water with high levels of organic contaminants and can enhance the removal of dissolved organic matter and microbial pathogens.

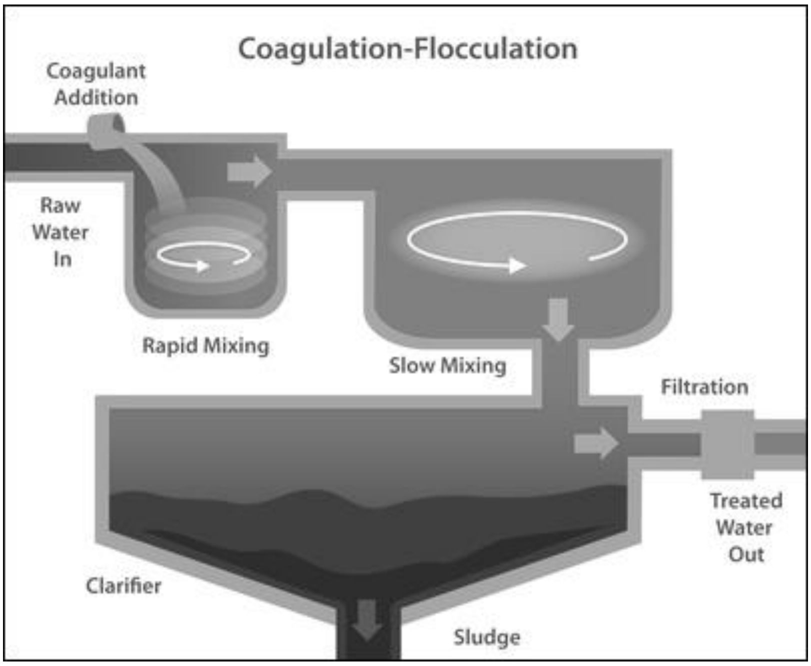

Fig 3.2. Coagulation-Flocculation

Flocculants

Flocculants are polymers that promote the formation of larger, settleable flocs during the flocculation process. Common flocculants include polyacrylamides (PAM), polyethyleneimine (PEI), and chitosan. Flocculants improve the settling characteristics of flocs, resulting in clearer supernatant and more efficient solids removal in sedimentation tanks or clarifiers.

Coagulation and flocculation agents are typically added to water or wastewater in controlled doses and mixed thoroughly to ensure proper dispersion and contact with suspended particles. The formed flocs settle out under gravity or are removed through filtration, allowing for the separation of clarified water from suspended solids and contaminants.

Overall, coagulation and flocculation play essential roles in pre-treating water and wastewater by improving the efficiency of subsequent treatment processes, reducing turbidity, enhancing clarification, and removing organic and particulate pollutants. Proper selection and dosage of coagulants and flocculants, along with optimized process conditions, are crucial for achieving effective pretreatment and ensuring the quality and safety of treated water.

Disinfection By-Products (DBPs)

Disinfection by-products (DBPs) are chemical compounds that are formed when disinfectants, such as chlorine, chloramines, chlorine dioxide, or ozone, react with organic and inorganic matter present in water during the disinfection process. These reactions can occur naturally in source water or be enhanced during water treatment processes, particularly when disinfectants are used to control microbial contaminants.

Common disinfection by-products include trihalomethanes (THMs), halo acetic acids (HAAs), chlorite, bromate, and chloramine-derived nitrogenous DBPs. THMs and HAAs are among the most frequently monitored DBPs and are formed through reactions between disinfectants (e.g., chlorine) and naturally occurring organic matter, such as humic and fulvic acids, in water. Bromate can form when ozone is used for disinfection in waters containing bromide ions. Exposure to disinfection by-products, particularly at high levels or over long periods, has been associated with potential health risks. Some DBPs have been classified as potential carcinogens or linked to adverse reproductive and developmental effects. Regulatory agencies, such as the U.S. Environmental Protection Agency (EPA) and the World Health Organization (WHO), establish maximum contaminant levels (MCLs) or guidelines for DBPs in drinking water to protect public health.

To minimize the formation of disinfection by-products, water treatment plants employ various strategies, including optimizing disinfection processes, controlling precursor levels through source water management, and implementing alternative disinfection methods such as UV radiation or advanced oxidation processes (AOPs). Additionally, treatment techniques such as granular activated carbon (GAC) filtration and membrane processes can help remove organic precursors before disinfection, reducing the formation of DBPs.Overall, managing disinfection by-products is essential for ensuring the safety and quality of drinking water. By understanding the formation mechanisms and implementing effective treatment and control measures, water utilities can minimize the risks associated with DBPs while maintaining effective disinfection to protect public health.

UNIT – IV

PHYSICAL DISINFECTION

Introduction

Physical disinfection methods play a crucial role in wastewater treatment, providing effective means to control and eliminate harmful microorganisms before treated wastewater is discharged into the environment or reused. Several physical disinfection techniques are employed in wastewater treatment plants, each offering unique advantages and applications. Ultraviolet (UV) irradiation is a commonly used method that utilizes UV light to damage the genetic material of microorganisms, preventing their replication and rendering them harmless. UV disinfection is highly effective against a wide range of pathogens, including bacteria, viruses, and protozoa, and it does not introduce chemical additives or produce harmful by-products. Another widely used physical disinfection method in wastewater treatment is ozonation, which involves the injection of ozone gas into wastewater to oxidize and deactivate microorganisms. Ozone's strong oxidizing properties enable it to disrupt cellular structures and metabolic processes in microorganisms, leading to their destruction. Additionally, ozonation can help control odor and remove organic contaminants, making it a versatile disinfection option. Both UV irradiation and ozonation offer efficient and environmentally friendly solutions for wastewater disinfection, contributing to the protection of public health and the environment. Proper implementation and monitoring of physical disinfection processes are essential to ensure the effectiveness and reliability of wastewater treatment systems, mitigating the risks associated with microbial contamination and safeguarding water resources for future generations.

Ultraviolet Radiation

Ultraviolet (UV) radiation is a widely used physical disinfection method in wastewater treatment, offering an effective means to control microbial contamination before treated wastewater is discharged into the environment or reused. UV disinfection works by exposing wastewater to UV light with wavelengths in the range of 200 to 300 nanometres, commonly referred to as UV-C light. This UV-C light penetrates the microbial cell walls and damages the genetic material (DNA or RNA) of microorganisms, preventing their replication and rendering them harmless. UV disinfection is highly effective against a broad spectrum of pathogens, including bacteria, viruses, and protozoa, without introducing chemical additives or producing harmful by-products.

In wastewater treatment plants, UV disinfection systems typically consist of UV lamps housed in protective sleeves submerged in the wastewater flow. The UV lamps emit intense UV light, which is absorbed by microorganisms present in the wastewater, leading to their inactivation. UV disinfection is often used as a final treatment step after primary and secondary treatment processes, such as sedimentation, filtration, and biological treatment, to ensure the removal of remaining pathogens.

One of the key advantages of UV disinfection in wastewater treatment is its ability to provide rapid and reliable microbial inactivation without the need for storage or contact time. UV disinfection systems can achieve high disinfection rates within seconds or minutes, making them well-suited for applications where rapid treatment is required. Additionally, UV disinfection does not alter the physical or chemical properties of the treated wastewater, preserving its quality and suitability for discharge or reuse.

However, UV disinfection systems require proper design, operation, and maintenance to ensure optimal performance. Factors such as UV lamp intensity, lamp age, water quality, and hydraulic conditions can influence the effectiveness of UV disinfection. Regular monitoring and validation of UV disinfection systems are essential to verify compliance with regulatory standards and ensure the protection of public health and the environment.

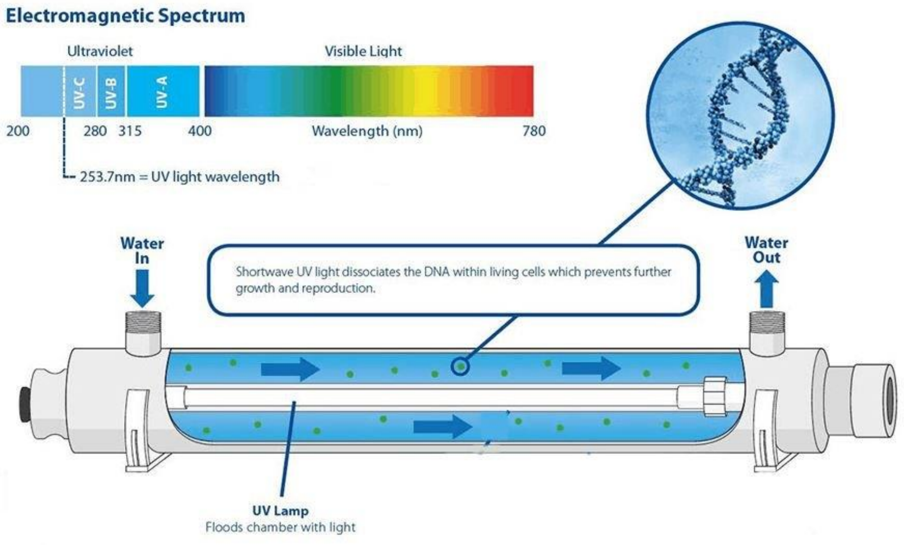

Fig 4.1. UV radiation apparatus

Overall, UV radiation is a reliable and environmentally friendly disinfection method for wastewater treatment, offering efficient microbial control and contributing to the safety and sustainability of water resources. Continued research and innovation in UV disinfection technology aim to enhance its efficiency, reliability, and applicability in various wastewater treatment scenarios.

Solar Disinfection

Solar disinfection, also known as SODIS, is a simple and low-cost method for treating drinking water in resource-limited settings, particularly in areas where access to clean water and conventional treatment methods is limited. The SODIS technique utilizes the natural disinfecting properties of sunlight to inactivate harmful microorganisms present in water, making it safe for consumption.

The SODIS process involves filling transparent PET (polyethylene terephthalate) bottles shown in Fig 4.2. with untreated water and exposing them to direct sunlight for a specified period, typically 6 to 8 hours, depending on solar intensity and weather conditions. During exposure to sunlight, two key mechanisms contribute to microbial inactivation: UV-A radiation and thermal effects.

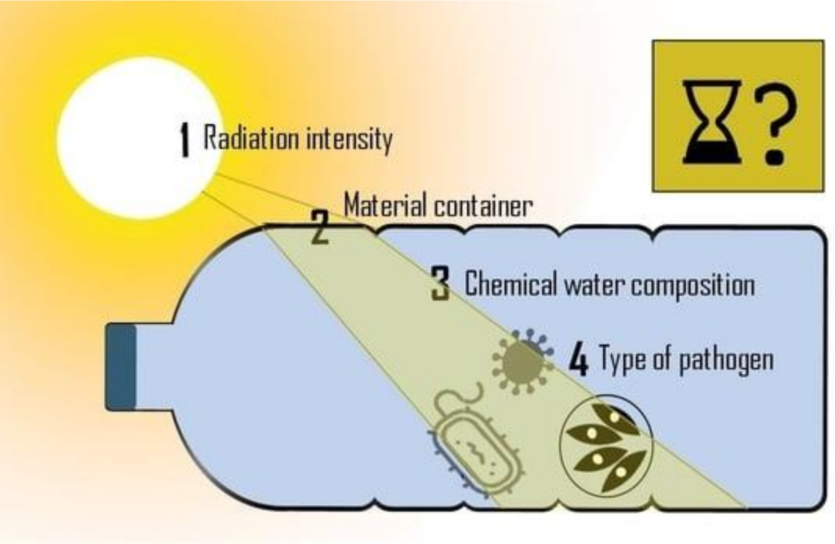

Fig 4.2. SODIS in PET (polyethylene terephthalate) bottles

UV-A radiation, present in sunlight, penetrates the water and damages the DNA of microorganisms, preventing their replication and rendering them harmless. The thermal effect of sunlight also contributes to microbial inactivation by raising the temperature of the water, further reducing microbial survival rates.

The SODIS method is effective against a wide range of pathogens, including bacteria, viruses, and protozoa, and has been shown to achieve up to 99.9% microbial reduction under optimal conditions. It is particularly well-suited for treating water contaminated with fecal pathogens, such as Escherichia coli (E. coli) and Rotavirus, commonly found in surface water sources.

One of the key advantages of SODIS is its simplicity and affordability, requiring minimal infrastructure and resources. PET bottles, readily available in many communities, serve as transparent containers for water disinfection, while sunlight provides the energy needed for the process. SODIS does not require consumables, chemicals, or electricity, making it suitable for use in remote or rural areas with limited access to conventional water treatment facilities.

However, SODIS also has limitations, including dependence on weather conditions and the availability of sunlight. Cloudy or overcast days may reduce solar radiation levels, prolonging the disinfection time required. Additionally, SODIS is primarily effective for treating small volumes of water and may not be suitable for large-scale water treatment applications.Overall, solar disinfection offers a simple, inexpensive, and environmentally friendly method for providing safe drinking water in resource-limited settings. When combined with education and hygiene promotion efforts, SODIS can contribute to improving public health outcomes by reducing waterborne diseases and promoting access to clean and safe drinking water. Ongoing research and community-based initiatives aim to further optimize and promote the adoption of SODIS as a sustainable water treatment solution.

Heat Treatment

Heat treatment is a physical disinfection method that utilizes high temperatures to control and eliminate harmful microorganisms from water, surfaces, and other environments.

Heat treatment works by denaturing the proteins and enzymes essential for microbial growth and survival, leading to the destruction of microorganisms.

In water treatment, heat treatment is commonly used to pasteurize or sterilize water, particularly in industries such as food and beverage processing, healthcare facilities, and laboratory settings. Pasteurization involves heating water to temperatures below its boiling point (typically between 60°C to 70°C) for a specified period to kill pathogenic bacteria, viruses, and other microbes while preserving its sensory and nutritional qualities. Pasteurized water is suitable for drinking and various industrial applications where microbial control is essential.

Sterilization, on the other hand, involves heating water to temperatures above its boiling point (typically above 100°C) to completely eradicate all viable microorganisms, including bacterial spores. Sterilized water is free from any microbial contamination and is commonly used in medical and laboratory procedures requiring the highest level of microbial control.

Heat treatment methods include boiling, autoclaving, and thermal pasteurization. Boiling water is the simplest form of heat treatment, involving heating water to its boiling point (100°C) for a specified period to achieve microbial inactivation. Autoclaving, also known as steam sterilization, utilizes high-pressure steam to heat water above its boiling point, effectively sterilizing it and eliminating all microbial contaminants, including spores. Thermal pasteurization involves heating water to lower temperatures for a longer duration, achieving microbial control while minimizing changes in water quality.

While heat treatment is highly effective in controlling microbial contamination, it may have limitations, such as energy requirements, potential alterations to water quality, and the need for specialized equipment for sterilization processes. Additionally, heat treatment may not be suitable for certain applications requiring preservation of water quality parameters or where energy resources are limited.

Overall, heat treatment is a valuable physical disinfection method for controlling microbial contamination in water and other environments, offering simplicity, effectiveness, and versatility in various applications. Proper implementation and monitoring of heat treatment processes are essential to ensure optimal microbial control while minimizing potential risks to human health and the environment.

Filtration Methods

Filtration methods are physical disinfection techniques that involve the removal of suspended solids, microorganisms, and other contaminants from water through the use of porous materials or membranes. These methods rely on physical barriers to trap and remove particles, pathogens, and other impurities, thereby improving water quality and reducing the risk of waterborne diseases. Filtration methods are commonly used in water and wastewater treatment, as well as in various industrial and residential applications.

There are several types of filtration methods, each offering unique advantages and applications:

Slow Sand Filtration: Slow sand filtration is a traditional and effective method for removing suspended solids, microorganisms, and organic matter from water. It involves passing water through a bed of fine sand at a slow rate, allowing biological processes and sedimentation to occur. Microorganisms and particles are trapped and biologically degraded within the sand bed, resulting in clear and microbiologically safe water.

Rapid Sand Filtration: Rapid sand filtration is a faster and more efficient variation of sand filtration commonly used in modern water treatment plants. It involves passing water through a bed of granular media (e.g., sand, anthracite) at a higher flow rate, typically aided by mechanical agitation or backwashing. Rapid sand filtration effectively removes suspended solids, turbidity, and some pathogens through physical straining and adsorption processes.

Membrane Filtration: Membrane filtration utilizes semi-permeable membranes with controlled pore sizes to selectively remove particles, microorganisms, and dissolved substances from water. Common membrane filtration processes include microfiltration (MF), ultrafiltration (UF), nanofiltration (NF), and reverse osmosis (RO), each offering different levels of filtration and separation. Membrane filtration is highly effective in removing bacteria, viruses, protozoa, and dissolved contaminants, making it suitable for producing high-quality drinking water and wastewater reuse applications.

Depth Filtration: Depth filtration involves passing water through a porous medium, such as diatomaceous earth, cellulose fibers, or activated carbon, to trap and remove particles and impurities. Depth filters operate through mechanisms such as mechanical straining, adsorption, and sedimentation, effectively removing suspended solids, colloids, and some microorganisms from water.

Bag and Cartridge Filtration: Bag and cartridge filtration utilize disposable filter bags or cartridges made of various materials (e.g., polypropylene, nylon, cellulose) to remove particles and contaminants from water. These filtration methods are commonly used in residential, commercial, and industrial applications for point-of-use or point-of-entry filtration, offering ease of installation and maintenance.

Distillation

Distillation is a physical process because it involves a phase change from liquid to gas (vapour), and then back again to liquid. Generally, no chemical change is intended to occur during the process of distillation. That said, some incidental or accidental chemical reactions may occur during the process of distillation. The risk of this happening increases as the scale becomes larger.

Distillation is a physical separation process employed to separate components of a liquid mixture through heating and cooling. It operates on the principle of differing boiling points of the components. In a typical setup, the liquid mixture is heated in a boiler or distillation flask, causing the component with the lowest boiling point to vaporize first. The vapours travel up a distillation column, where they encounter a cooler surface, leading to condensation and collection in a receiver flask. This process continues, enriching the collected liquid in the lower boiling point component. Various types of distillation exist, such as simple distillation for significantly different boiling points and fractional distillation for closer boiling points. Distillation finds application in water purification, alcohol separation, crude oil refining, and chemical synthesis, making it a fundamental process in numerous industries.

The distillation process begins with heating a liquid mixture in a boiler or distillation flask, causing the component with the lowest boiling point to vaporize. These vapours rise through a distillation column, encountering a cooler surface where condensation occurs. The condensed vapours collect in a condenser, where they return to liquid form. This condensed liquid, now separated from the original mixture, is collected in a receiver flask. Each repetition of this process enriches the collected liquid in the lower boiling point component.

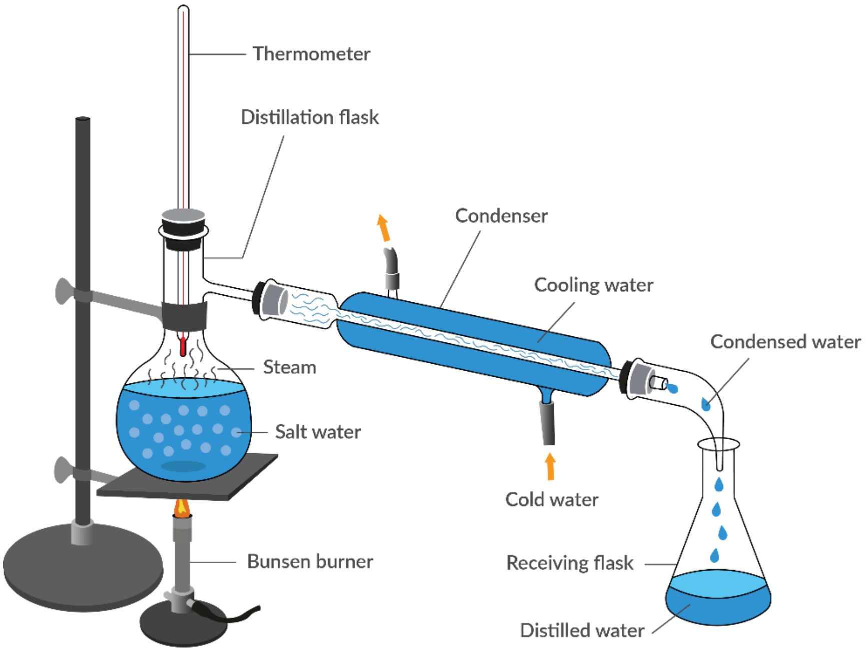

Fig 4.3. Distillation setup

Electro chemical Oxidation Water Disinfection by Microwave Heating.

Electrochemical oxidation and water disinfection by microwave heating are two distinct methods for treating water, each with its own principles and applications.

Electrochemical Oxidation:

Electrochemical oxidation involves using an electrical current to drive oxidation reactions that eliminate contaminants in water. Typically, this process occurs in an electrolytic cell where electrodes are immersed in the water. When an electrical current is applied, oxidation reactions take place at the anode, generating reactive oxygen species such as hydroxyl radicals. These reactive species are highly effective at breaking down organic pollutants, pathogens, and other contaminants present in the water. Electrochemical oxidation can be a sustainable and efficient method for water treatment, particularly for removing organic pollutants and disinfecting water.

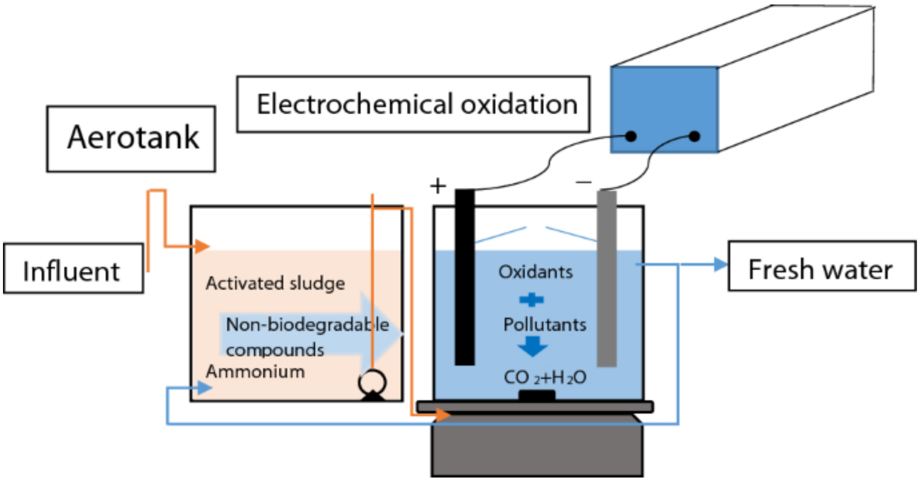

Fig 4.4. Electrochemical oxidation setup

Water Disinfection by Microwave Heating:

Water disinfection by microwave heating utilizes electromagnetic radiation in the microwave frequency range to heat water and inactivate microorganisms. Microwave radiation causes water molecules to oscillate, generating heat through friction. This heat can effectively kill or inactivate bacteria, viruses, and other pathogens present in the water. Microwave heating for water disinfection is a rapid and energy-efficient method that can be particularly useful in situations where conventional disinfection methods such as chlorination or UV irradiation are impractical or insufficient. However, it's important to ensure uniform heating throughout the water to achieve effective disinfection.

Both electrochemical oxidation and water disinfection by microwave heating offer unique advantages for water treatment, and their suitability depends on factors such as the type of contaminants present, the desired level of disinfection, and the available resources and infrastructure. Integrating these technologies with existing water treatment processes can enhance overall treatment efficiency and ensure the production of safe and clean water for various applications.