Jan 2024

2024 January

8. Explain, with the aid of sketches, the principles of reverse osmosis as a method of producing fresh water. (10)

sept 2020

Sept 2020

7. Explain, with the aid of sketches, the principles of reverse osmosis as a method of producing fresh water. (10)

Reverse osmosis (RO) is a water purification technique that utilizes a semi-permeable membrane to separate dissolved contaminants from water. Here's a breakdown of the principles behind it:

Natural Osmosis:

Imagine a container divided by a semi-permeable membrane separating salty water (high solute concentration) from pure water (low solute concentration). Osmosis, a natural process, will cause the pure water to flow through the membrane towards the saltier side. This happens because water molecules are constantly moving, and the semi-permeable membrane only allows them to pass through, not the salt ions. This movement of water molecules tries to balance the concentration of solutes on both sides.

Reverse Osmosis:

In RO, we apply pressure to the salty water side, overcoming the natural osmotic pressure. This applied pressure forces the pure water molecules from the salty water solution to pass through the membrane in the opposite direction of natural osmosis, hence the term "reverse." The filtered water, devoid of most salts and impurities, is collected on the other side of the membrane as permeate. The remaining concentrated brine solution (reject water), containing the filtered-out contaminants, is discharged from the system.

Key Components:

- **Semi-permeable membrane:** This is the heart of RO, allowing only water molecules to pass through while rejecting most dissolved ions and larger molecules.
- **High-pressure pump:** This pump pressurizes the feed water (salty water) to overcome the osmotic pressure and drive the process.
- **Pre-treatment (optional):** Depending on the feed water quality, pre-treatment steps like filtration or chlorination might be necessary to protect the RO membrane from damage.

Applications:

Reverse osmosis is a versatile and efficient method for desalination, turning seawater or brackish water into fresh water for various purposes:

- **Drinking water:** RO is widely used to produce clean drinking water from saline sources, especially in regions with limited freshwater resources.
- **Industrial processes:** RO purified water is used in various industries where high-purity water is required, such as electronics manufacturing and pharmaceutical production.
- **Irrigation:** RO can help reduce salinity in water used for agriculture, protecting crops from salt damage.

Limitations:

- **Energy consumption:** The high-pressure pump requires significant energy to operate.
- **Membrane maintenance:** RO membranes are susceptible to fouling and require periodic cleaning or replacement.
- **Wastewater disposal:** The concentrated brine solution from RO needs proper disposal to avoid environmental impacts.

Overall, reverse osmosis is a powerful technology for producing fresh water from various saline sources, playing a crucial role in water security and sustainable water management.

aug 2023

AUG 2023

7. (a) Describe, with the aid of a sketch, a reverse osmosis plant, from feed water inlet, to product tank, labelling ALL components and showing the position in the system of the monitoring instruments. (7)

(b) Describe the feed water pre-treatment process before the water enters the spirally wound membrane modules. (3)

10

Reverse Osmosis Plant: Feed Water to Product Tank

(a) System Components and Monitoring:

A reverse osmosis plant consists of several stages, each playing a crucial role in purifying the water. Here's a breakdown from feed water inlet to the product tank:

1. **Feed Water Inlet:** Raw water enters the plant, often from a well, seawater source, or municipal supply.
2. **Pre-treatment:** This stage removes impurities that could damage the RO membrane. Depending on the feed water quality, it may involve:
   - **Multimedia Filter:** Removes suspended particles like sand, silt, and debris.
   - **Activated Carbon Filter:** Absorbs chlorine, organic contaminants, and taste/odor causing substances.
   - **Antiscalant Dosing:** Chemicals are added to prevent scaling on the membrane from minerals like calcium and magnesium.
   - **Monitoring Instruments:** Pressure gauges, flow meters, and turbidity meters monitor pre-treatment performance.
3. **High-Pressure Pump:** This pump increases the pressure of the pre-treated water to overcome the osmotic pressure and drive water through the membrane.
   - **Monitoring Instruments:** Pressure gauges and flow meters monitor pump performance and feed water pressure.
4. **Spiral Wound Membrane Modules:** These house the semi-permeable membranes that allow water molecules to pass through while rejecting contaminants. The system typically uses multiple membrane modules arranged in series or parallel for increased efficiency.
   - **Monitoring Instruments:** Conductivity meters monitor permeate (product water) quality, indicating its purity. Pressure gauges monitor pressure across the membrane modules.
5. **Permeate Tank:** The filtered, low-salinity water (permeate) is collected and stored in this pressurized tank.
   - **Monitoring Instruments:** Level sensors and pressure gauges monitor the permeate water level and pressure in the tank.
6. **Brine Reject Stream:** The concentrated brine solution containing the rejected salts and impurities is discharged from the system. The discharge location depends on regulations and may involve further treatment.
   - **Monitoring Instruments:** Conductivity meters or salinity sensors monitor the concentration of the reject stream.

(b) Feed Water Pre-treatment Process:

Pre-treatment is crucial for protecting the RO membrane and ensuring efficient operation. Here's a closer look:

1. **Multimedia Filtration:** Water passes through a series of graded layers of filter media (sand, gravel, etc.) that trap suspended particles like dirt, silt, and organic matter.
   - **Benefit:** Protects the membrane from physical damage caused by large particles.
2. **Activated Carbon Filtration:** Water flows through activated carbon, a highly adsorbent material that removes chlorine, taste/odor causing compounds, and some organic contaminants.
   - **Benefit:** Prevents chlorine from damaging the membrane and improves permeate quality.
3. **Antiscalant Dosing:** Chemicals are added to the pre-treated water to prevent scaling on the membrane from minerals like calcium and magnesium. These antiscalants bind to the minerals, keeping them in solution and preventing them from precipitating on the membrane surface.
   - **Benefit:** Extends membrane life and maintains RO system efficiency.

The specific pre-treatment steps and chemicals used will depend on the quality of the feed water entering the plant.

june 2021

June 2021

8. Describe, with the aid of a sketch, the construction of a spirally wound membrane suitable for use in a Reverse Osmosis water making plant, identifying ALL component parts. (10)

april 2021

April 2021

8. Describe, with the aid of a sketch, the construction of a spirally wound membrane suitable for use in a Reverse Osmosis water making plant, identifying ALL component parts. (10)

Anatomy of a Spiral Wound Membrane for Reverse Osmosis

A spiral wound membrane is the heart of a reverse osmosis (RO) system, responsible for separating pure water from dissolved contaminants. Here's a breakdown of its construction:

Components:

1. **Permeate Spacer (Permeator):** This is a mesh-like structure placed on the feed water side of the membrane. Its function is multifold:
   - **Create a channel:** It creates a defined channel for the feed water to flow along the membrane surface.
   - **Promote turbulence:** The mesh disrupts the formation of a stagnant layer of concentrated brine solution next to the membrane, improving mass transfer and efficiency.
   - **Support the membrane:** It provides structural support to the thin membrane layer, preventing collapsing under pressure.
2. **Feed Channel (Feed Spacer):** This is another spacer located between the permeate spacer and the membrane. It helps maintain a consistent distance between the membrane and the permeate spacer, ensuring proper flow and preventing the membrane from collapsing.

3. **Semi-permeable Membrane:** This is the core of the assembly, typically made from a thin layer of polyamide (e.g., Nylon-6) or other selective polymers. It has a microporous structure that allows water

molecules to pass through while rejecting most dissolved ions and larger molecules.

4. **Backing Material:** This non-permeable layer supports the thin membrane film from the high-pressure feed water on the other side. It's typically made from a strong and chemically resistant material like polyester or polysulfone.

5. **Feed Spacer Carrier:** This is a perforated tube that houses the permeate spacer and feed channel. It allows the feed water to flow into the permeate spacer channel and provides structural support for the entire assembly.

6. **Brine Channel Collector:** This is a channel on the other side of the membrane where the concentrated brine solution (reject stream) containing the filtered-out contaminants accumulates.

Construction Process:

1. The permeate spacer and feed channel are often pre-assembled.
2. The flat sheet membrane is then laminated onto the backing material.
3. The entire assembly is then wrapped around a perforated central core, forming a spiral configuration. This maximizes the membrane surface area within the pressure vessel housing the modules.
4. The edges of the membrane are sealed to prevent leakage.

Benefits of Spiral Wound Design:

- High packing density: The spiral design allows for a large membrane surface area within a compact module, maximizing water production capacity.
- Efficient flow: The spacers promote even flow distribution across the membrane surface, improving mass transfer and system performance.
- Cost-effective: The modular design allows for easy replacement of individual modules if needed.

Overall, the spiral wound membrane's construction combines selective permeability with efficient flow dynamics, making it a key component for reverse osmosis water purification.

30 October 2020

7. With reference to reverse osmosis plants:

(a) describe the sea water pre-treatment process before the water enters the membrane modules; (6)

(b) describe how the purity of the permeate is measured; (3)

(c) state the limits of impurity in the permeate when produced to World Health Organisation Standards. (1)

Seawater Pre-treatment for Reverse Osmosis

(a) Pre-Treatment Stages:

Seawater pre-treatment is essential for protecting the RO membrane and ensuring efficient operation in a desalination plant. Here's a breakdown of the key stages:

1. **Coarse Filtration:** Removes large suspended solids like sand, silt, and debris. This can be achieved through:

    - **Intake Screens:** Filter out large debris at the seawater intake point.

  - **Traveling Band Screens or Strainers:** Continuously remove larger particles from the seawater stream.

2. **Coagulation/Flocculation (Optional):** This step is used if the seawater has high levels of turbidity or organic matter. It involves adding coagulant chemicals that cause suspended particles to clump together (flocculate) and then settle out or get removed by subsequent filtration.

3. **Media Filtration:** Water passes through a series of graded layers of filter media (sand, gravel, anthracite) that trap smaller particles, including flocculated material and some microorganisms.

4. **Cartridge Filtration:** Often used as a final polishing step to remove any remaining particulates that could damage the RO membrane.

5. **Chlorination (Optional):** Chlorine or chlorine dioxide may be added to disinfect the seawater and control biological growth. However, this needs careful management to avoid damaging the RO membrane.

6. **Antiscalant Dosing:** Chemicals are added to prevent scaling on the membrane from minerals like calcium and magnesium. These antiscalants bind to the minerals, keeping them in solution and preventing them from precipitating on the membrane surface.

(b) Measuring Permeate Purity:

The purity of the permeate (treated water) in an RO system is primarily measured by its electrical conductivity (EC) or total dissolved solids (TDS).

- **Electrical Conductivity (EC):** This method measures the ability of a solution to conduct electricity, which is directly related to the concentration of dissolved ions in the water. Lower EC values indicate higher water purity.
- **Total Dissolved Solids (TDS):** This method measures the total amount of dissolved solids (organic and inorganic) present in the water. Lower TDS values indicate lower impurity levels.

Monitoring instruments:

- Conductivity meters are the most common tools for continuous monitoring of permeate quality.
- Grab samples of permeate might be analyzed periodically using laboratory techniques to measure specific dissolved ions or contaminants.

(c) WHO Limits for Permeate Purity:

The World Health Organization (WHO) publishes guidelines for drinking water quality in its "Guidelines for drinking-water quality". While not a strict regulation, these guidelines provide a framework for ensuring safe drinking water.

There's no single limit for all impurities in permeate. However, WHO recommends the following general guidelines for some key parameters:

- **Electrical Conductivity (EC):** Less than 250 μS/cm (microsiemens per centimeter) at 25°C.
- **Total Dissolved Solids (TDS):** Ideally less than 500 mg/L (milligrams per liter). However, this value can be adjusted based on local circumstances and palatability considerations.

It's important to note that these are just general guidelines. Specific requirements for permeate quality might vary depending on local regulations and intended use of the desalinated water.

feb 2021

Feb 2021

7. (a) Describe, with the aid of a sketch, the operation of the silver ion method of water sterilisation. (6)

(b) Describe how Ultra Violet Light can be used to kill bacteria in potable water. (2)

(c) Explain the disadvantages of using Ultra Violet Light as a method of sterilisation, stating how this may be overcome. (2)

Water Sterilisation Methods: Silver Ion and Ultraviolet Light

(a) Silver Ion Method:

The silver ion method is a popular technique for disinfecting water, particularly for point-of-use applications or in storage tanks. Here's how it works:

- **Silver Ions Release:** Silver ions (Ag^+) are released into the water through various methods:
    - **Electrolysis:** An electric current is passed through silver electrodes, causing silver atoms to dissolve and release ions into the water.
    - **Silver-impregnated media:** Cartridges containing ceramic or other materials infused with silver slowly release silver ions as water flows through them.
- **Mechanism of Action:** Silver ions have a strong antimicrobial effect. They disrupt the cell membranes of bacteria, viruses, and other microorganisms, interfering with their vital functions and leading to their death.
- **Benefits:**
    - Effective against a broad spectrum of bacteria, viruses, and some fungi.
    - Long-lasting residual effect: Silver ions remain active in the water for some time, providing ongoing protection.
    - Generally safe for humans at recommended concentrations.
- **Limitations:**
    - Ineffective against protozoa (like Giardia) and some parasites.
    - Not as effective in turbid water as silver ions can bind to suspended particles and become less available.
    - Regular monitoring of silver ion concentration is necessary to ensure effectiveness and safety.

(b) Ultraviolet (UV) Light Sterilisation:

Ultraviolet (UV) light is another effective method for disinfecting water. Here's its operation:

- **Wavelength:** Specifically, UV light within the germicidal range (200-280 nm) is used.
- **Mechanism:** UV light disrupts the DNA and RNA of microorganisms, preventing them from reproducing and rendering them inactive.
- **Benefits:**
    - Fast and effective against a broad spectrum of bacteria, viruses, and protozoa.
    - No residual chemicals left in the water.
    - Relatively simple technology.

- **Disadvantages:**
    - Limited penetration: UV light only disinfects clear water. Turbidity, organic matter, and color can significantly reduce its effectiveness.
    - No residual effect: Microorganisms entering the treated water after disinfection are not affected.
    - Requires pre-treatment: Water may need filtration or clarification to ensure optimal UV penetration.

(c) Overcoming UV Light Limitations:

Several strategies can be employed to address the limitations of UV disinfection:

- **Pre-treatment:** Implementing filtration or clarification steps before UV treatment can significantly improve water clarity and maximize UV effectiveness.
- **Higher UV Dose:** Increasing the UV light intensity or exposure time can compensate for some turbidity issues. However, this needs to be balanced with energy consumption and potential lamp degradation.
- **Combined Treatment:** UV light can be combined with other methods like chlorination. This approach provides a broader spectrum of disinfection and can offer residual protection against post-treatment contamination.

By addressing these limitations, UV light remains a valuable tool for water disinfection, especially in applications where simple and rapid treatment is desired.

aug 2021

Aug 2021

7. Sketch a line diagram of a single pass reverse osmosis plant. (10)

A single-pass reverse osmosis (RO) plant is a simplified system for purifying water. Here's a breakdown of its operation:

Components:

1. **Feed Water Inlet:** Raw water enters the plant, often from a well, brackish water source, or municipal supply.
2. **Pre-treatment (Optional):** Depending on the feed water quality, some pre-treatment steps like multimedia filtration or activated carbon filtration might be included to remove impurities that could damage the membrane.
3. **High-Pressure Pump:** This pump increases the pressure of the pre-treated water to overcome the natural osmotic pressure and drive water through the membrane.
4. **Spiral Wound Membrane Module:** This module houses the semi-permeable membrane that allows water molecules to pass through while rejecting contaminants. A single-pass system typically uses one or a few modules.
5. **Permeate Tank:** The filtered, low-salinity water (permeate) is collected in this pressurized tank.

Operation:

- Pre-treated water is pressurized by the pump.
- The high-pressure water enters the spiral wound membrane module.
- Water molecules pass through the membrane due to the pressure difference, leaving the dissolved salts and other contaminants behind.
- This filtered water (permeate) is collected in the permeate tank.
- The remaining concentrated solution, containing the rejected impurities, exits the system as a waste stream (reject or brine). This stream typically represents 20-25% of the original feed water volume.

Benefits:

- Simpler design compared to multi-pass systems.
- Lower initial investment cost.

Limitations:

- Lower water recovery rate: A significant portion of the feed water becomes waste due to single-pass operation. This can be a disadvantage in areas with limited water resources.
- Lower permeate quality: Single-pass systems may not achieve the same level of purity as multi-pass systems that recycle some of the permeate for further treatment.

Applications:

- Single-pass RO is suitable for applications where lower water recovery is acceptable and moderate water quality improvement is sufficient.
- Examples include pre-treatment for other purification systems, industrial process water, or brackish water desalination in areas with less stringent water quality requirements.

nov 2020

Nov 2020

7. With reference to reverse osmosis plants:

(a) explain the treatment that the feedwater undergoes to prevent blockage of the membranes; (3)

(b) describe how the purity of the water is measured and protected, stating the limits on purity set by the World Health Organisation; (5)

(c) outline the further treatment the permeated water undergoes before it can be used for domestic purpose. (2)

Reverse Osmosis Plant: Feedwater Treatment, Purity Monitoring, and Domestic Use

(a) Preventing Membrane Blockage:

To prevent blockage of the delicate membranes in a reverse osmosis (RO) plant, the feedwater undergoes several pre-treatment steps:

- **Coarse Filtration:** Removes large suspended solids like sand, silt, and debris using screens, strainers, or media filters.
- **Coagulation/Flocculation (Optional):** This step (used if necessary) removes smaller particles and organic matter by adding coagulants that cause them to clump together (flocculate) for easier removal by subsequent filtration.
- **Media Filtration:** Water passes through layers of sand, gravel, or other media to trap smaller particles that could damage or clog the membrane.
- **Cartridge Filtration:** Often used as a final polishing step to remove any remaining particulates.
- **Chlorination (Optional):** Chlorine or chlorine dioxide might be added in low doses to control biological growth that could foul the membrane. However, careful management is needed to avoid damaging the membrane itself.
- **Antiscalant Dosing:** Chemicals are added to prevent scaling on the membrane from minerals like calcium and magnesium. These antiscalants bind to the minerals, keeping them in solution and preventing them from precipitating on the membrane surface.

(b) Monitoring and Protecting Water Purity:

Measurement:

- **Electrical Conductivity (EC):** Measures the ability of the solution to conduct electricity, indicating the concentration of dissolved ions (lower EC = higher purity).
- **Total Dissolved Solids (TDS):** Measures the total amount of dissolved solids (organic and inorganic) present in the water (lower TDS = lower impurity).

Protection:

- **Membrane Integrity:** Regular monitoring and replacement of membranes are crucial to maintain their effectiveness in rejecting impurities.
- **Pre-treatment Efficiency:** Ensuring proper pre-treatment reduces the load on the membrane and protects it from damage or fouling.
- **Antiscalant Dosing:** Maintaining the appropriate dosage of antiscalants prevents mineral scaling on the membrane surface.

WHO Limits:

The World Health Organization (WHO) publishes guidelines for drinking water quality in its "Guidelines for drinking-water quality". While not a strict regulation, these guidelines provide a framework for ensuring safe drinking water.

There's no single limit for all impurities in permeate. However, WHO recommends the following general guidelines for some key parameters:

- **Electrical Conductivity (EC):** Less than 250 μS/cm (microsiemens per centimeter) at 25°C.
- **Total Dissolved Solids (TDS):** Ideally less than 500 mg/L (milligrams per liter). However, this value can be adjusted based on local circumstances and palatability considerations.

(c) Further Treatment for Domestic Use:

While RO permeate is relatively pure, it may require additional treatment before it's suitable for domestic use:

- **Remineralization (Optional):** The RO process removes most minerals from the water. In some cases, minerals may be added back to improve taste and address potential health concerns related to long-term consumption of demineralized water.
- **pH Adjustment:** RO permeate can be slightly acidic due to the presence of carbon dioxide. Adjustment to a slightly alkaline pH range (around 7.0-8.5) might be necessary to improve taste and prevent corrosion in pipes.
- **Disinfection:** Depending on the feed water source and local regulations, additional disinfection with chlorine or another method may be required to ensure microbiological safety.

Note: The specific treatment steps for permeate before domestic use will depend on local regulations, feed water quality, and desired water characteristics.

oct 2018

Oct 2018

7. (a) Describe, with the aid of a sketch, a reverse osmosis plant, from feed water inlet, to product tank, labelling ALL components and showing the position in the system of the monitoring instruments. (7)

(b) Describe the feed water pre-treatment process before the water enters the spirally wound membrane modules. (3)

Reverse Osmosis Plant: Feedwater to Product Tank

A reverse osmosis (RO) plant consists of several stages working together to purify water. Here's a breakdown from feed water inlet to product tank, including monitoring instruments:

Components and Monitoring:

1. **Feed Water Inlet:** Raw water enters the plant, often from a well, seawater source, or municipal supply.
2. **Pre-treatment (with Monitoring Instruments):** This stage removes impurities that could damage the RO membrane. Depending on the feed water quality, it may involve:
    - **Multimedia Filter:** Removes suspended particles like sand, silt, and debris.
        - **Monitoring:** Pressure gauges monitor filter performance.
    - **Activated Carbon Filter:** Absorbs chlorine, organic contaminants, and taste/odor causing substances.
        - **Monitoring:** Pressure gauges monitor filter performance.
    - **Antiscalant Dosing System:** Chemicals are added to prevent scaling on the membrane.
        - **Monitoring:** Conductivity meters monitor antiscalant concentration in the feed water.
    - **Coagulation/Flocculation (Optional):** This step removes smaller particles and organic matter (if needed).
        - **Monitoring:** pH meters monitor the optimal coagulation process.
3. **High-Pressure Pump:** This pump increases the pressure of the pre-treated water to overcome the osmotic pressure and drive water through the membrane.
    - **Monitoring:** Pressure gauges and flow meters monitor pump performance and feed water pressure.
4. **Spiral Wound Membrane Modules:** These house the semi-permeable membranes that allow water molecules to pass through while rejecting contaminants. The system typically uses multiple membrane modules arranged in series or parallel for increased efficiency.
    - **Monitoring:** Conductivity meters monitor permeate (product water) quality, indicating its purity. Pressure gauges monitor pressure across the membrane modules.
5. **Permeate Tank:** The filtered, low-salinity water (permeate) is collected and stored in this pressurized tank.
    - **Monitoring:** Level sensors and pressure gauges monitor the permeate water level and pressure in the tank.
6. **Brine Reject Stream:** The concentrated brine solution containing the rejected salts and impurities is discharged from the system. The discharge location depends on regulations and may involve further treatment.
    - **Monitoring:** Conductivity meters or salinity sensors monitor the concentration of the reject stream.

Feedwater Pre-treatment Process

Pre-treatment is crucial for protecting the RO membrane and ensuring efficient operation. Here's a closer look:

1. **Coarse Filtration:** Water passes through a series of graded layers of filter media (sand, gravel, etc.) that trap suspended particles like dirt, silt, and organic matter.
    - **Benefit:** Protects the membrane from physical damage caused by large particles.
2. **Activated Carbon Filtration:** Water flows through activated carbon, a highly adsorbent material that removes chlorine, taste/odor causing compounds, and some organic contaminants.
    - **Benefit:** Prevents chlorine from damaging the membrane and improves permeate quality.
3. **Antiscalant Dosing:** Chemicals are added to the pre-treated water to prevent scaling on the membrane from minerals like calcium and magnesium. These antiscalants bind to the minerals, keeping them in solution and preventing them from precipitating on the membrane surface.
    - **Benefit:** Extends membrane life and maintains RO system efficiency.
4. **Coagulation/Flocculation (Optional):** This step is used if the seawater has high levels of turbidity or organic matter. It involves adding coagulant chemicals that cause suspended particles to clump together (flocculate) and then settle out or get removed by subsequent filtration.
    - **Benefit:** Removes smaller particles and organic matter that could foul the membrane.

The specific pre-treatment steps and chemicals used will depend on the quality of the feed water entering the plant.

march 2021

March 21

6. (a) State THREE types of micro-organisms that may exist in water. (3)

(b) Describe, with the aid of a sketch, the operation of a *Silver Ion Sterilizer.* (7)

Bacteria: These are single-celled organisms, some of which can cause a variety of illnesses like diarrhea, cholera, and E. coli infections if ingested in contaminated water.

1. **Viruses:** Even smaller than bacteria, viruses are not technically living organisms but can replicate inside host cells. They can cause waterborne illnesses like hepatitis A and rotavirus.

2. **Protozoa:** These single-celled organisms are larger than bacteria and can be motile (move on their own). Examples include Giardia lamblia, which can cause giardiasis, a diarrheal illness.

Silver Ion Sterilization

Silver ion sterilization is a method for disinfecting water using positively charged silver ions (Ag+). Here's how it works:

1. **Silver Ion Release:** Silver ions are released into the water through various methods:
   - **Electrolysis:** An electric current is passed through silver electrodes, causing silver atoms to dissolve and release ions into the water.
   - **Silver-impregnated media:** Cartridges containing ceramic or other materials infused with silver slowly release silver ions as water flows through them.
2. **Mechanism of Action:** Silver ions have a strong antimicrobial effect. They disrupt the cell membranes of bacteria, viruses, and other microorganisms. This disrupts essential cellular functions and leads to their death.

- **Disruption of cell membranes:** Silver ions can interact with the cell membrane of microorganisms, causing it to become leaky and lose essential cellular components.
- **Inhibition of enzyme activity:** Silver ions can also bind to and inactivate enzymes within the microorganism, hindering their ability to function and reproduce.
- **DNA and RNA damage:** In some cases, silver ions can damage the DNA or RNA of the microorganism, preventing it from replicating.

3. **Benefits:**

- **Effective against a broad spectrum of bacteria, viruses, and some fungi.**
- **Long-lasting residual effect:** Silver ions remain active in the water for some time, providing ongoing protection.
- **Generally safe for humans at recommended concentrations.**

4. **Limitations:**

- **Ineffective against protozoa (like Giardia) and some parasites.**
- **Not as effective in turbid water:** Silver ions can bind to suspended particles and become less available to target microorganisms.
- **Regular monitoring of silver ion concentration is necessary** to ensure effectiveness and safety. Silver at high concentrations can be harmful to humans.

aug 2021

Aug 2021

6. With reference to the risk of legionella bacteria in air conditioning plants:

(a) state FOUR main areas which are considered to be a breeding ground for the bacteria, outlining a reason for EACH; (8)

(b) describe how the risks of the existence of the bacteria can be reduced. (2)

Legionella in Air Conditioning Systems: Breeding Grounds and Risk Reduction

(a) Legionella Breeding Grounds in Air Conditioning:

Legionella bacteria can thrive in specific areas within air conditioning (AC) systems, posing a health risk. Here are four key breeding grounds and the reasons for their suitability:

1. **Cooling Towers:** These large structures cool water used in AC systems. The combination of warm water, spray, and scale buildup creates a perfect environment for Legionella growth.
2. **Evaporative Condensers:** Similar to cooling towers, these use water evaporation for heat exchange. The presence of warm water and potential for mist formation can harbor Legionella.
3. **Air Handling Units (AHUs):** These units contain humidifiers or spray chambers for humidity control. Stagnant water, especially with organic matter or biofilm buildup, can provide a breeding ground for the bacteria.
4. **Domestic Hot Water Systems:** Legionella can also multiply in hot water tanks or poorly maintained domestic hot water systems connected to AC units, particularly if the water temperature doesn't reach sufficiently high levels for disinfection.

(b) Reducing Legionella Risks in AC Systems:

Several strategies can be implemented to minimize the risk of Legionella growth in air conditioning systems:

1. **Temperature Control:** Maintaining water temperatures below 20°C (68°F) or above 60°C (140°F) in cooling towers, evaporative condensers, and hot water systems hinders Legionella growth.
2. **Disinfection:** Regular disinfection with chlorine, ozone, or ultraviolet (UV) light can effectively kill Legionella bacteria present in the water systems.
3. **Water Treatment:** Implementing water treatment programs that control scale, biofouling (organic buildup), and corrosion within the AC system can reduce the availability of nutrients and attachment sites for Legionella.
4. **System Maintenance:** Regular cleaning and maintenance of cooling towers, AHUs, and associated water systems help prevent stagnant water and biofilm formation, which can harbor Legionella. This includes inspections for scale buildup and proper drainage to avoid water accumulation.
5. **Monitoring and Testing:** Regular monitoring of water temperature and implementing Legionella testing protocols can help detect potential problems before they cause an outbreak.

By implementing these control measures, building owners and managers can significantly reduce the risk of Legionella growth within their air conditioning systems and protect public health.

aug 2020

Aug 2020

8. (a) State TWO methods of producing fresh water on board an ocean going vessel. (2)

(b) State TWO methods of killing the bacteria which may be present in the water. (2)

(c) Explain the reasons for adding hydrated lime to water produced on board an ocean going vessel. (3)

(d) Outline the procedure to be followed before a fresh water tank is brought back into service. (3)

Fresh Water Production and Disinfection on Ocean Vessels:

Fresh Water Production:

1. **Reverse Osmosis (RO):** This is a widely used method where seawater is forced through a semi-permeable membrane, allowing water molecules to pass through while rejecting dissolved salts and impurities. RO systems require pre-treatment to protect the membranes and produce high-quality drinking water.

2. **Distillation:** This traditional method boils seawater to produce steam, which is then condensed into pure water. While effective, distillation is energy-intensive and requires regular cleaning of the evaporator units due to scale buildup.

Killing Bacteria:

1. **Chlorination:** Low levels of chlorine are often added to the produced freshwater to kill bacteria. Continuous or shock chlorination methods can be employed. However, careful monitoring is necessary to avoid excessive chlorine levels, which can affect taste and potentially create harmful byproducts.

2. **Ultraviolet (UV) Light:** UV disinfection disrupts the DNA of bacteria, rendering them inactive. This method is quick, effective, and doesn't leave any residual chemicals in the water. However, UV light only penetrates clear water, so pre-filtration or proper maintenance to minimize turbidity is crucial.

Hydrated Lime Addition:

Hydrated lime (calcium hydroxide) is commonly added to water produced on board ships for several reasons:

- **pH Adjustment:** Fresh water produced by RO or distillation tends to be slightly acidic due to dissolved carbon dioxide. Lime increases the pH level to a slightly alkaline range (around 7.0-8.5) for several benefits:
    - Improves taste
    - Reduces pipe corrosion
    - Provides a slight residual disinfection effect
- **Precipitation of Metals:** Lime can help precipitate out some dissolved metals like iron and manganese, which can improve water quality and aesthetics.

Fresh Water Tank Re-commissioning:

Before bringing a freshwater tank back into service after cleaning or repairs, a specific procedure is followed to ensure the safety of the water:

1. **Physical Cleaning:** The tank is thoroughly cleaned to remove any debris, rust, or scale buildup. This might involve mechanical cleaning, high-pressure washing, and disinfection with a suitable solution.
2. **Disinfection:** The tank is then disinfected using a method like chlorine or a chlorine dioxide solution. The specific concentration and contact time will depend on regulations and the chosen disinfectant.
3. **Neutralization:** After disinfection, the chlorine residual needs to be neutralized with a dechlorination agent like sodium thiosulfate to ensure acceptable taste and prevent pipe corrosion.
4. **Flushing and Testing:** The tank is flushed thoroughly with clean water to remove any residual disinfectant or cleaning chemicals. Water samples are then taken for microbiological testing to ensure the absence of harmful bacteria before the tank is released for use.

These steps ensure that the freshwater tank is clean, free of harmful bacteria, and ready to provide safe drinking water for the crew and passengers.

jan 2021

29 January 2021

7. With reference to water treatment:

(a) state the treatment required for fresh water taken on from ashore; (2)

(b) state FOUR properties required for water used for domestic purposes, describing how this may be achieved in EACH case. (8)

Water Treatment: Onshore Intake and Domestic Properties

(a) Treatment for Onshore Fresh Water:

Depending on the source and local regulations, onshore fresh water might require minimal or additional treatment before being suitable for shipboard use:

- **Minimal Treatment:** If the source is a well-maintained municipal supply with established quality control, minimal disinfection with chlorine or UV light might be sufficient.
- **Additional Treatment:** If the source is unknown or of questionable quality, further treatment steps might be necessary:
  - **Filtration:** To remove suspended particles, turbidity, and any residual chlorine present in some municipal supplies.
  - **Reverse Osmosis (Optional):** If the water has high salinity or requires further reduction in dissolved minerals.
  - **Disinfection:** Ensuring proper disinfection with chlorine or UV light to eliminate any potential bacterial contamination.

The specific treatment steps will depend on the quality of the onshore water source and the ship's own treatment capabilities.

(b) Properties of Domestic Water and Treatment Methods:

1. **Microbiologically Safe:** The water must be free from harmful bacteria, viruses, and parasites that can cause waterborne diseases.
- **Treatment:** Disinfection with chlorine, UV light, or other approved methods to kill or inactivate microorganisms.
2. **Clear and Colorless:** The water should be visually appealing, free from turbidity, and have no noticeable color.

- **Treatment:** Filtration to remove suspended particles and organic matter that can cause cloudiness or color.

3. **Pleasant Taste and Odor:** The water should be palatable and free from objectionable tastes or odors.

- **Treatment:**
    - **Activated Carbon Filtration:** Absorbs chlorine, organic compounds, and other taste/odor causing substances.
    - **Aeration:** Can help remove volatile compounds that contribute to unpleasant odors.
    - **pH Adjustment:** Balancing the pH level (around 7.0-8.5) can improve taste.

4. **Low in Dissolved Minerals:** While some minerals are essential, excessively high levels can make the water taste salty or hard (causing scale buildup).

- **Treatment:**
    - **Reverse Osmosis (Optional):** For significant reduction in dissolved minerals, especially in cases of high salinity.
    - **Ion Exchange (Optional):** Can be used to selectively remove specific minerals like calcium and magnesium responsible for water hardness.

By implementing these treatment methods, shipboard water treatment systems can ensure that the water taken on board meets the necessary domestic water quality standards.

may 2021

May 2021

8. With reference to fresh water treatment:

(a) describe the process for superchlorinating the fresh water system, stating relevant periods, times, and chlorine levels; (6)

(b) explain what is meant by copper staining and the treatment required to prevent it. (4)

Fresh Water Treatment: Superchlorination and Copper Staining

(a) Superchlorination Process:

Superchlorination is a shock treatment method used to disinfect a freshwater system on board a ship and eliminate any potential bacterial growth, particularly Legionella bacteria. Here's a breakdown of the process:

- **Preparation:**
    - Isolate the freshwater system from other onboard water supplies to prevent contamination.
    - Ensure proper ventilation in pump rooms and other enclosed spaces where chlorine will be used.
    - Crew members involved should wear appropriate personal protective equipment (PPE) like gloves, goggles, and respirators.
- **Chlorine Dosing:**
    - Introduce a high concentration of chlorine into the freshwater system, typically exceeding 1 mg/L (milligrams per liter) free chlorine residual.
    - This can be achieved through various methods:
        - Sodium hypochlorite (bleach) solution
        - Electrolytic generation of chlorine
        - Chlorine gas (used less frequently due to safety concerns)
- **Contact Time:**

  - Maintain the high chlorine concentration for a specific period, typically between 1-4 hours. This allows sufficient time for the chlorine to come into contact and inactivate bacteria throughout the system.
- **Dechlorination:**
  - After the contact time, the chlorine residual needs to be neutralized to prevent taste issues and pipe corrosion. This is done by adding a dechlorination agent like sodium thiosulfate.
- **Flushing and Testing:**
  - The entire system is thoroughly flushed with clean water to remove any residual chlorine or dechlorination byproducts.
  - Water samples are taken at various points in the system for microbiological testing to ensure the absence of harmful bacteria before the system is returned to service.

Important Notes:

- The specific chlorine concentration, contact time, and dechlorination procedures might vary depending on regulations, the type of chlorine used, and the initial water quality.
- It's crucial to follow established protocols and manufacturer's recommendations for safe and effective superchlorination.

(b) Copper Staining and Prevention:

Copper Staining:

This refers to the appearance of blue-green or turquoise stains on fixtures and surfaces that come into contact with the ship's freshwater. These stains are caused by the corrosion of copper pipes or fittings within the system.

Causes:

- **Low pH:** When the freshwater is slightly acidic (low pH), it can become corrosive to copper pipes.
- **High Oxygen Levels:** Dissolved oxygen in the water can also accelerate copper corrosion.

Prevention:

Several strategies can be implemented to prevent copper staining:

- **pH Adjustment:** Maintaining a slightly alkaline pH level (around 7.0-8.5) in the freshwater can help reduce copper pipe corrosion. This can be achieved by adding hydrated lime (calcium hydroxide) during water treatment.
- **Corrosion Inhibitors:** Phosphate-based corrosion inhibitors can be added to the freshwater system to form a protective film on the copper surfaces, slowing down corrosion.
- **Cathodic Protection (Optional):** In some cases, a cathodic protection system might be used to electrically protect the copper pipes from corrosion.

By implementing these preventive measures, shipboard water treatment systems can minimize the risk of copper staining and ensure the aesthetic quality and safety of the freshwater supply.