



Learning Science via Standards



Drinking Water



IS 14543

CM/L-XXXXXXXXXX

Lesson 47
Aug 2023



Nurturing Young Minds as Ambassadors of Quality and Standards



Foreword

Everything around us, whether natural phenomena or manmade products can be explained through science. The product which are used in our daily life are outcome of conscious efforts by the mankind to fulfil and exceed the needs of the present and demands of the future. Students are taught science as part of their school curriculum, to enable them to understand the various scientific laws and principles and also to inculcate the habit of exploring the world through the lens of science. Quality characteristics of any product or service are decided based on the stated and implied needs and are generally described in a document called 'Standard'. Science and standards are inseparable and integral aspect of any product.

Bureau of Indian Standards (BIS), the national standards body of India, is mandated for establishment and promotion of standards and creating a quality ecosystem in the country. This is achieved through developing Indian Standards on products and services through the active involvement of relevant stakeholders and dissemination of information of such standards for their use and implementation across all sectors of economy. Academia, as an important stakeholder of BIS, has been contributing towards development of standards through research activities and providing inputs related to technological advancements in product development, their characteristics and use as well as methods of tests. BIS, on its part has also been promoting standards in academia through a variety of programmes. This has since been institutionalized in the form of "Standards Clubs" which are being established in educational institutions across India to nurture the young minds as ambassadors of quality and standards and prepare them for dealing with these aspects in future.

In this initiative of BIS, called "Learning Science via Standards", a series of Lesson Plans are made elaborating the various scientific concepts, laws and principles to help students understand their practical applications via standards. The series comprises of a variety of subjects for insights into the scientific laws and principles and relating them to the quality characteristics of products used in day-to-day life. First 10 Lesson Plans in the series are released on the occasion of World Consumer Rights Day on 15 Mar 2023. Second Set of 10 Lesson Plans were released on 10 Jun 2023 by Hon'ble Minister of State during the Governing Council Meeting of BIS.

The Lesson Plans are expected to serve as a useful tool for the teaching fraternity for imparting knowledge on scientific laws and principles through their practical applications in activities and products around us and facilitate an interactive learning experience for the students.



Packaged Drinking Water

Water's history is a profound tale, spanning Earth's formation 4.6 billion years ago, when it gathered in the atmosphere and birthed our oceans. Vital for life, water enabled the emergence of early organisms in ancient oceans around 3.5 billion years ago. Beyond Earth, water's presence on the Moon and Mars fuels space exploration dreams.

Water is an inorganic compound with the chemical formula H_2O . It is a transparent, tasteless, odourless, and nearly colourless chemical substance, and it is the main constituent of Earth's hydrosphere and the fluids of all known living organisms.

Water covers about 71% of the Earth's surface, with seas and oceans making up most of the water volume. Small portions of water occur as groundwater, in the glaciers and the ice caps of Antarctica and Greenland, and in the air as vapor, clouds (consisting of ice and liquid water suspended in air), and precipitation.

It's influence on civilizations is evident as cultures settled near rivers for sustenance and trade, culminating in advanced irrigation during the Agricultural Revolution. However, industrialization brought pollution and urbanization strained clean water access. This prompted the rise of water treatment and heightened environmental concern. Presently, water scarcity and pollution persist as global challenges demanding coordinated efforts.



Why water molecule exists as liquid at room temperature and pressure while many other heavier molecules like CO_2 , NO_2 , H_2S , SO_2 are gases?

In water molecules due to large difference in affinity of electrons between oxygen and hydrogen atoms, negative and positive charge gets accumulated respectively on these atoms. The negative and positive charges form polar bonds with adjacent molecules thereby forming a chain of molecules. This polar bonding between molecules causes water to exist in liquid state.

Packaged Drinking Water is drinking water packaged in plastic or glass water bottles. PET bottles are more common due to its light weight and resistance to breaking. In India, the packaged drinking water industry witnessed a boom in the late 1990s soon after Bisleri launched its packaged drinking water in the country.



1. Indian Standards for Safe Drinking Water intended for human consumption

a) IS 10500 Specification for Drinking water

Drinking water is water intended for human consumption for drinking and cooking purposes from any source. It includes water (treated or untreated) supplied by any means for human consumption. This standard prescribes the requirements and the methods of sampling and test for drinking water



b) IS 14543 Specification for Packaged Drinking Water.

This standard prescribes the requirements and methods of sampling and test for Packaged Drinking water (other than Natural Mineral water) offered for consumption and/or for sale in packaged form. Packaged Drinking water means water, other than natural mineral water that is likely to be used for human consumption and that is offered or sold in packaged form, by whatever name it may be called, offered or sold.

c) IS 13428 Specification for Natural Mineral water.

Natural Mineral water is obtained directly from natural or drilled sources from underground water-bearing strata for which all possible precautions should be taken within the protected perimeters to avoid any pollution of, or external influence on, the chemical and physical qualities; it is characterized by its content of certain mineral salt and the irrelative proportions and the presence of trace elements or of other constituents; of the constancy of its composition and the stability of its discharge and its temperature, due account being taken of the cycles of minor natural fluctuations; it is collected under conditions which guarantee the original microbiological purity and chemical composition of essential components; it is packaged close to the point of emergence of the source with particular hygienic precautions; and it is not subjected to any treatment other than those permitted by this standard.



Why PET bottles are transparent?

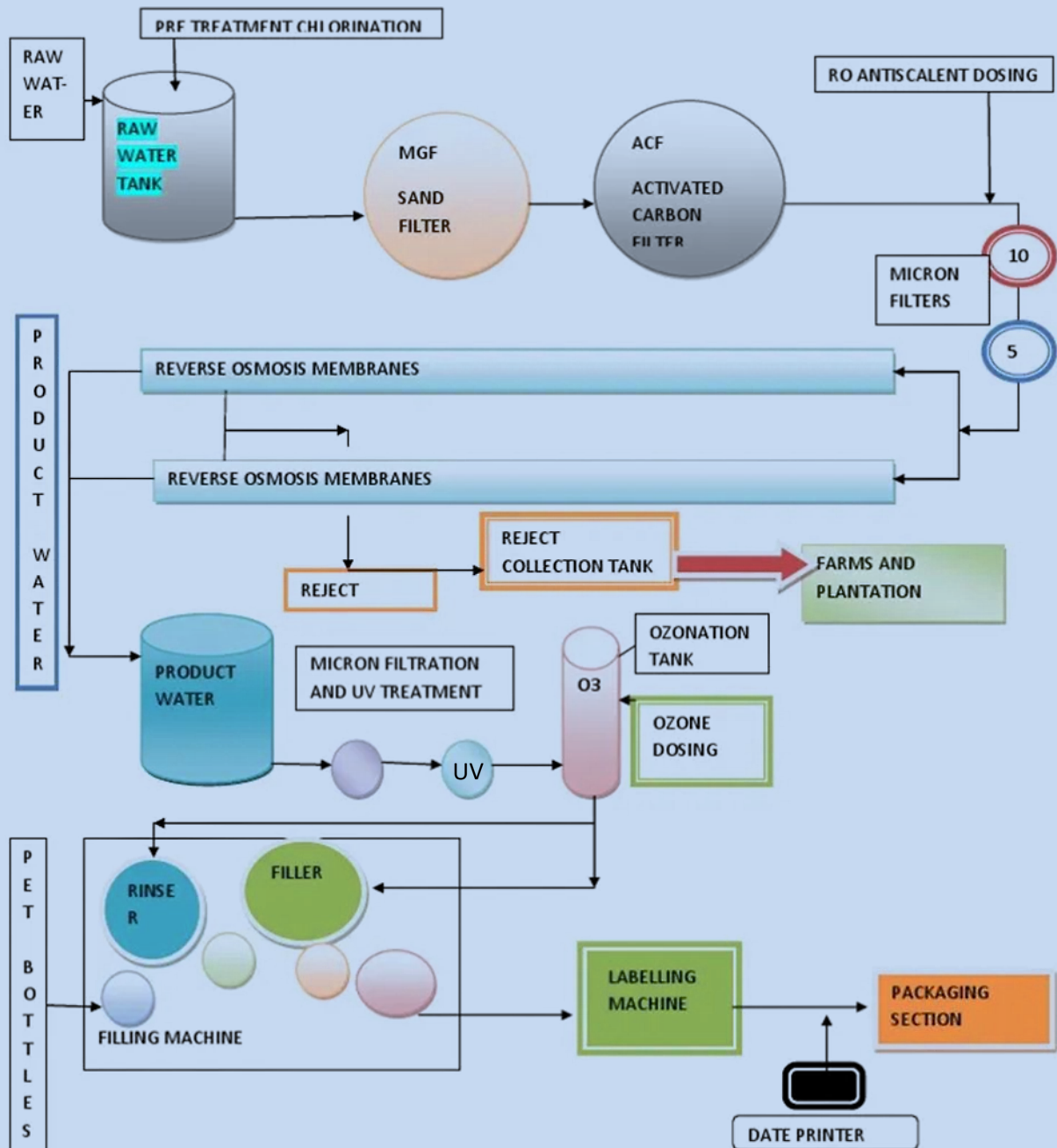
Crystalline polymers are generally non-transparent or opaque due to scattering of light between closed packed layers. On the other hand, Polyethylene Terephthalate is an amorphous polymer with a liner structure and scattering of light is very less in this material.

2. Manufacturing process

Following treatment steps are involved in the manufacturing process of Packaged Drinking Water:

- a) **Dosing System 1 & 2** - The water is drawn from Bore Well line. The water is then collected to storage tank. It then goes to dosing system through raw water feed pump. In the dosing system, anti-scalent is used for the softening of the water.
- b) **Pressure Sand Filter** - From dosing system water goes to pressure sand filter, where the impurities of raw water are removed.

c) **Activated Carbon Filter** - From pressure sand filter water goes to activated carbon filter



where organic impurities are removed.

d) **Micron Cartridge Filter (MCF)** - Water is then passed through micron filter. This filter removes the micron particles from the water.

e) **Demineralisation by Reverse Osmosis System (R.O.)** - Water from MCF goes to R.O. System through High Pressure Pump. R.O. removes 90-95% of dissolved solids. The finished water is passed into Storage Tank.

- f) Ozone Generator with Re-Circulation** - Finished water from R.O. system is stored in S.S made storage tank. The tank is provided with the Manhole so that the tank can be cleaned. This tank is used as ozone circulation tank. The ozone is passed to this tank for disinfections.
- g) U.V. System** - Water from S.S. tank is passed through MCF to U.V. disinfection system, where the bacteria are inactivated.
- h) Filling and Packing** - Water is then filled in cleaned and rinsed containers.
- i) Visual Examination** - Containers are visually inspected for any leakage and suspended matter against illuminated screen.



How Ultraviolet Light is used in disinfection of water?

UV-C light has a wavelength of approximately 200 to 280 nanometres (nm), which falls within the germicidal range. This light is absorbed by the genetic material (DNA or RNA) of microorganisms and forms covalent bonds between adjacent thymine (T) or uracil (U) bases. This bonding creates thymine dimers in DNA or uracil dimers in RNA.

Thymine or uracil dimers disrupt the normal structure of genetic material and prevent the microorganisms from replicating accurately. When bacteria or viruses cannot reproduce properly, their ability to infect and multiply in host cells is compromised.

3. Quality Parameters of Packaged Drinking Water

Water quality can be defined based on a set of biological, physical and chemical variable, which are closely linked to the water's intended use. As a principle, drinking water is supposed to be free from harmful pathogens and toxic chemicals.

a) Organoleptic and Physical Parameters

Physical quality parameters are related to total solids content, which is composed of floating matter, settleable matter, colloidal matter and matter in solution. The following physical parameters are determined in Packaged drinking water:

- i. **Colour** caused by dissolved organic materials from decaying vegetation or landfill leachate. The packaged drinking water should be transparent in colour.
- ii. **Taste and odour** can be caused by foreign compounds such as organic compounds, inorganic salts or dissolved gases. The water should be pleasant in taste and should be odourless. Any deviation from acceptable taste or odour standards can result in the water being deemed unfit for sale or consumption.



- iii. **Turbidity** refers to the presence of suspended solid materials in water such as clay, silt, organic material, plankton, and so on. In the context of packaged drinking water, turbidity can have several effects, both on the water's quality and its appearance.

It is measured in Nephelometric Turbidity Units (NTU). Higher NTU values indicate greater turbidity, which can result from soil erosion, organic matter, pollutants, or microbial activity. Turbidity affects water quality by reducing light penetration and providing a habitat for microorganisms. It's a key parameter in assessing water health, as elevated turbidity can impact drinking water treatment processes.

Monitoring turbidity helps ensure safe water supplies, maintain aquatic habitats, and protect public health by preventing the spread of waterborne diseases.



How Turbidity in water can be measured?

Nephelometry measures the scattering of light by particles in a liquid to determine turbidity. A light source, typically a laser or LED, emits light into the liquid sample. Photodetectors positioned at an angle to the light source measure the intensity of the scattered light at that specific angle. The amount of scattered light is directly related to the turbidity of the liquid; higher turbidity results in more scattering.

- iv. **Total Dissolved Solids (TDS)** refers to the cumulative concentration of dissolved inorganic and organic substances in water, typically measured in parts per million (ppm) or milligrams per liter (mg/L). TDS includes minerals, salts, metals, and other compounds that have dissolved into the water from natural sources like rocks and soil, as well as human activities such as industrial discharges and agricultural runoff. High TDS levels can affect water taste, corrode pipes, and impact aquatic ecosystems. TDS serves as an important indicator of water quality, influencing its suitability for drinking, irrigation, and various industrial processes. Balancing TDS is crucial for maintaining safe and sustainable water resources. As per the Indian Standards IS 14543, the maximum limit of Total Dissolved Solids is 500.



- v. **pH Values:** The pH of water is a very important measurement concerning water quality. pH, or "potential of hydrogen," is a measure of the acidity or alkalinity of a solution on a logarithmic scale ranging from 0 to 14. pH of water is a critical parameter determining its acidity or alkalinity. Pure water has a neutral pH of 7, indicating a balance between hydrogen (H⁺) and hydroxide (OH⁻) ions. Solutions with a pH below 7 are acidic, while those above 7 are alkaline.

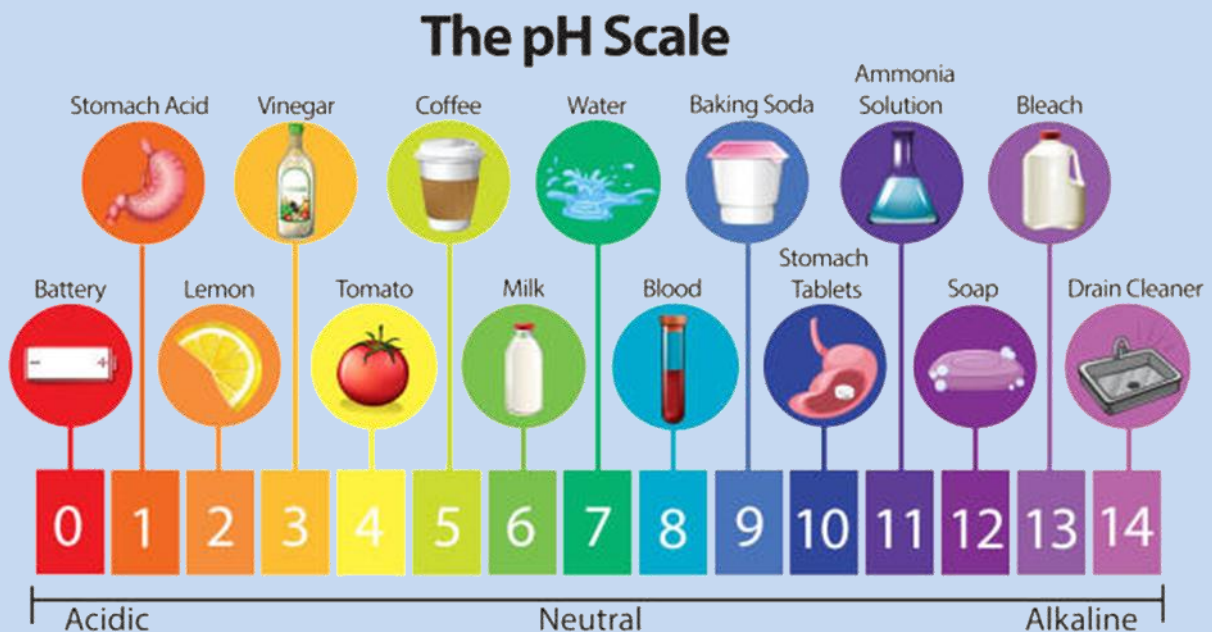
Litmus paper is a simple pH indicator that changes color when dipped into solutions of different pH levels. Red litmus paper turns blue in basic solutions, while blue litmus paper turns red in acidic solutions.



How pH meter changes colour?

The reason for this colour change is due to the chemical composition of litmus paper. Litmus is a natural dye extracted from lichens, particularly species like *Rocella tinctoria* and *Lecanora tartarea*. Litmus contains pH-sensitive compounds known as lichen dyes. These dyes can exist in different forms depending on the pH of the solution they are in.

Monitoring and maintaining appropriate water pH levels are vital for environmental sustainability and human health.



b) Chemical parameters

The chemical constituents have more health concerns for drinking water than for the physical constituents. Major chemical parameter that affect health:

- i. **Arsenic:** occurs naturally in some geologic formation. It is mostly used in agricultural chemicals. It has been linked to lung and urinary bladder cancer.
- ii. **Chloride:** most waters contain some chloride as it is used as a disinfectant in water treatment to kill bacteria and other pathogens. It is important to keep the chlorine content within safe limits to avoid any potential effect on the human body.
- iii. **Fluoride:** is a natural contaminant of water. High Fluoride in drinking water usually causes dental and skeletal fluorosis which occurs when a person is exposed to high levels of fluorides over a prolonged period.
- iv. **Antimony:** Can cause nausea, vomiting and diarrhea. Continued exposure to high level of antimony can lead to increases in blood cholesterol and decreases in blood sugar. Borate can cause developmental effects.





How high fluoride content in water causes fluorosis?

During tooth development, exposure to excessive fluoride can affect the enamel-forming cells, leading to alterations in the enamel's mineralization process. Mild dental fluorosis may result in small white streaks or spots on the teeth. These are generally cosmetic concerns. In more severe cases, dental fluorosis can lead to brown staining and pitting of the teeth, which can affect both the appearance and structural integrity of the teeth.

- v. **Phenolic compounds, mineral oil:** causes highly objectionable odour and taste and renders water unpalatable.
- vi. **Nitrate:** High Nitrate content can cause *Methemoglobinemia (Blue Baby Syndrome)* in infants.
- vii. **Barium:** Not carcinogenic or genotoxic. Some evidence of causing acute hypertension
- viii. **Bromate:** Bromate is harmful in high doses. Causes gastrointestinal symptoms such as nausea, vomiting, diarrhea, abdominal pain, and kidney effects,
- ix. **Toxic Heavy Metals** The toxic heavy metals are arsenic (As), barium (Ba), cadmium (Cd), chromium (Cr), lead (Pb), mercury (Hg), selenium (Se) and silver (Ag) [. Some of these substances are acute poisons (As and Cr) and others produce chronic diseases (Pb, Cd and Hg).
- x. **Pesticide residues:** Main source of contamination is from agricultural sources.
- xi. **Radiological Toxicity:** Specific to some area with radioactive resources. Detrimental to health like cause of cancer, morbid birth defects etc.

c) Biological parameters

Biological parameters are the basic quality parameters for the control of diseases caused by pathogenic organisms, which have human origin. Pathogenic organisms found in surface water include bacteria, fungi, algae, protozoa, plants and animals and viruses.

The requirement and absence of these substances should be in accordance with the following parameters



- i. **E coli, coliform, faecal, Sulphite reducing anaerobes** – It should be absent as it may lead to mild diarrhoea or more severe outcomes in case of pathogenic strains (enterohemorrhagic, enteropathogenic, enterotoxin) of coliform such as jaundice, or internal bleeding.
- ii. **Staphylococcus aureus, P. aeruginosa-** It should be absent from drinking water as they could cause minor skin infections to major diseases like pneumonia, meningitis.
- iii. **Aerobic Microbial Count-** It shall not exceed 100/ml at 20 to 22°C in 72 h and 20/ ml at 37 ± 1°C in 24 h. Aerobic Microbial Count is not a health threat in itself, however, it's an indicator of cleanliness and hygienic conditions.



- iv. **Salmonella, Shigella, Vibrio cholera and V. parahaemolyticus** – It should also be absent from packaged drinking water. These are pathogens which can cause mild afflictions (cramps, diarrhea) as well as severe illnesses (cholera, typhoid/enteric fever).

d) Characteristics of Container/bottles

To maintain the quality of packaged drinking water, it is imperative to have packaging material of good quality. Some of the important tests carried out on the packaging containers are:

- i. **Transparency** – For storing Packaged drinking water, the transparency of the container should not be less than 85 percent.
- ii. **Migration** – These tests assess whether any substances from the bottle materials can migrate into the water and potentially pose health risks to consumers. This test is critical for safeguarding consumer health, ensuring product quality, preventing contamination, and maintaining a positive brand image.



How do plastic material migrate into water?

Plastic materials are made of one or more monomers and several additives that can eventually migrate into water, either during bottle manufacturing, water filling or storage. The main reasons for this migration is due to exposure to high energy radiation like UV light or due to temperature. The bonds in polymer chains may break due to these reasons and the monomer may migrate into water.

4. Important Concepts and laws:

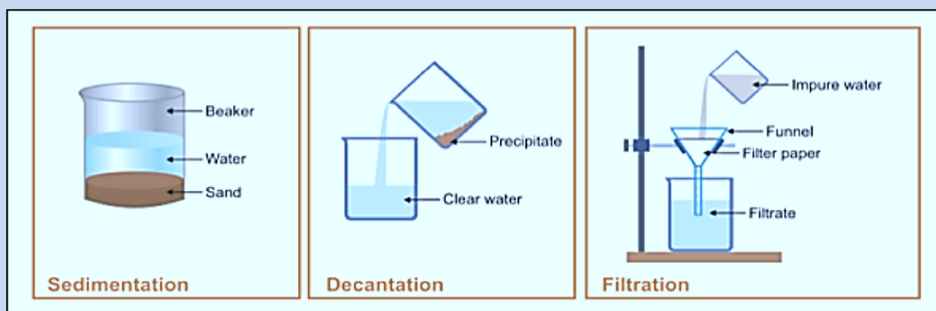
Various techniques like sedimentation, decantation, filtration, reverse osmosis, disinfection through chemical agents.

a. Sedimentation

It is the process used to separate solids from a liquid. “When the heavier component in a mixture settles after water is added to it, the process is called sedimentation”.

b. Decantation

When the heavier component in a mixture settles after water is added to it, the process is called sedimentation. When the water along with the dust is removed, the process is called decantation.



c. Filtration

Filtration is the separation process where insoluble impurities are separated from the solution. This process requires the use of filter paper, where the solution is poured into the filter paper, the insoluble impurities get collected on the filter paper and the clear liquid passes through it. For example: separating tea leaves from tea with the help of a strainer.

d. Reverse osmosis (RO)

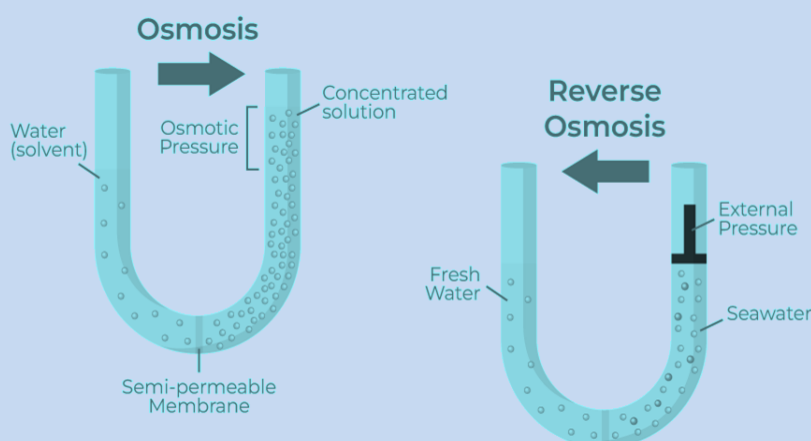
It is a process wherein a pressure greater than the osmotic pressure is added on the solution side of the semipermeable membrane (abbreviated to SPM) to cause the pure solvent to pass through the semipermeable membrane and gather in a separate area.

To understand what reverse osmosis is, it is important to first understand what osmosis is.

Osmosis is the movement of the molecules of the solvent from an area where the concentration of the solute is low, through a semipermeable membrane, to an area where the concentration of solute is high. The process of osmosis can be halted by applying some amount of pressure to the solution side of the semipermeable membrane. This minimum pressure required to halt the process of osmosis is called osmotic pressure. Osmotic pressure can also be used to measure the tendency of solvents to pass through the SPM to the region of higher solute concentration via osmosis.

Now that the process of osmosis is understood, the question – What is reverse osmosis? Can be answered in a simple and clear manner. As discussed above, Osmotic pressure is the minimum pressure that must be applied to stop the flow of the solvent through the semipermeable membrane.

Now, when a pressure greater than the osmotic pressure is applied on the solution side (the side where the concentration of solute is high), the solvent particles on the solution side pass through the semipermeable membrane to the area where the concentration of solute is low. This reversed flow of the solvent through the SPM is called reverse osmosis.



Note that the pressure applied on the solution side must be higher than the osmotic pressure for the reverse osmosis process to proceed.

e. Disinfection through Chlorination and Ozonation

Chlorine kills pathogens such as bacteria and viruses by breaking the chemical bonds in their molecules. Disinfectants that are used for this purpose consist of chlorine compounds which can exchange atoms with other compounds, such as enzymes in bacteria and other cells. Chlorination is the most commonly used disinfection for water.



Ozone is a very strong oxidant and virucide. Ozone is a molecular compound of three oxygen atoms (O_3), in which two oxygen atoms from the basic oxygen molecule (O_2 – the oxygen that humans breathe) and contains a third oxygen atom that can easily detach from the ozone compound and reattach to other molecules. When this third oxygen atom, called a radical, attaches to the molecules of other substances, it can break down their structure and destroy them.

5. Interesting Facts

- a) The world's oldest bottled water brand is Apollinaris, founded in 1852 in Germany. It is still popular and widely available today.
- b) Radioactive residues test is also carried out on the packaged drinking water in India before Licence is granted to start production and also at regular intervals post production.
- c) Despite efforts to promote recycling, only a small percentage of plastic water bottles get recycled globally. The majority end up in landfills or as litter.
- d) Different countries have different regulations and standards for bottled water quality. The World Health Organization (WHO) sets international guidelines, and many national regulatory bodies enforce their own standards.
- e) In many developed countries, tap water is generally safe to drink and undergoes rigorous testing.
- f) The bottled water industry offers various specialty waters, such as mineral water, spring water, artesian water, and alkaline water, each claiming unique health benefits.
- g) Astronauts on the International Space Station (ISS) consume packaged drinking water specially designed for space missions.
- h) One can find many details like manufacturer's name, shelf life, ISI Licence number, Indian standard number by looking at the label of the packaged drinking water.

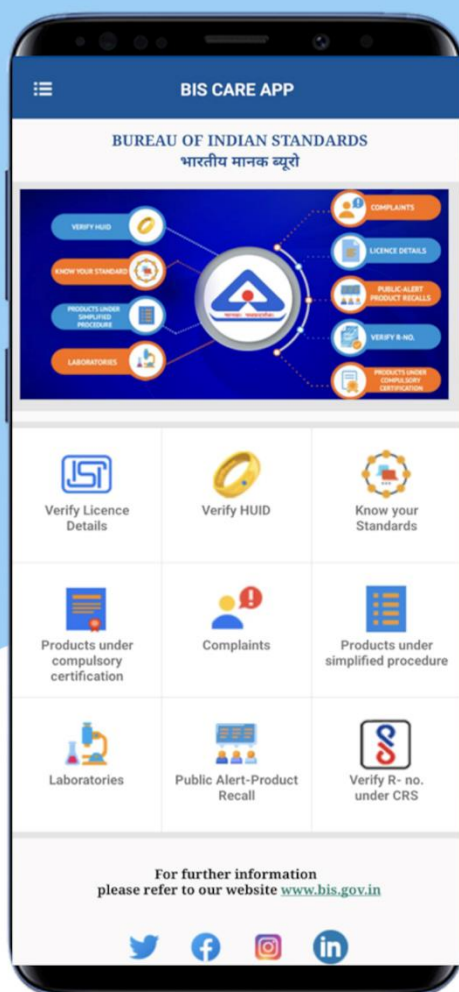
Lesson Plan Subjects

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1.	Caustic Soda	27.	Plugs and Socket
2.	Football	28.	Solar Flat Plate Collectors
3.	Cement	29.	Precast Concrete
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7.	LED Bulb	33.	Thermometer
8.	LPG Cylinders	34.	Tyres for buses and trucks
9.	Cement Ash Brick	35.	Vacuum Flask
10.	Paints	36.	Water Meter
11.	Boric Acid	37.	Wheel Rim
12.	Ceiling Fan	38.	Water Storage Tank
13.	Cables	39.	PVC Pipes
14.	Ceramics Tiles	40.	Refrigerator
15.	Rear View Mirrors	41.	CNG Cylinders
16.	Headphones	42.	Hearing Aids
17.	Milk Powder	43.	Microwave Oven
18.	Pressure Cooker	44.	Solid and Hollow Block
19.	Plywood	45.	Submersible Pump set
20.	Multipurpose dry batteries	46.	Conduits
21.	Ballpoint Pen	47.	Drinking Water
22.	Bicycle	48.	Electric Mixer
23.	Electric Iron	49.	Family Sized Biogas Plant
24.	Loudspeakers	50.	Fire Extinguisher
25.	Pasteurized Milk	51.	Power Threshers
26.	Paver Blocks	52.	Geosynthetics



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