REPORT

# Water for Everyone: Safe and Sustainable

**Rhea Gupta**
Class XI, The Shri Ram School Araval

**Duration:** Jun 2022 to Sep 2022

**Mentors:** Anup Thakur (Senior Group Leader RD&E, Ecolab); Ajit Unhale (Senior Chemist RD&E, Ecolab); Shubham Patil (Chemist RD&E, Ecolab)

## ABSTRACT

This report details the importance of sufficient clean water, the impact of insufficient or unsafe water, and the methods of water treatment with their impact on environmental sustainability. Our bodies are made of 60% water that continually depletes due to breathing, sweating and digestion. Each of us needs 8-10 glasses of water daily and more water for other purposes such as cleaning and sanitation. The benefits of water in the human body are many – from inducing weight loss to helping fight fatigue, strengthen immune system, give life to kidneys, lubricate joints, help digest food, improve skin and reduce muscle inflammation. Lack of clean drinking water can lead to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio. Industries need water for almost all parts of their manufacturing and engineering processes. The importance of water cannot be overstated. Yet only 74% of the world population has access to safely managed drinking water services (1.6 billion people lack such a basic need in their lives); 80% of these disadvantaged people live in rural areas.

There are various methods of water treatment to remove various pollutants such as suspended solids, biodegradable organics, pathogens, nutrients (nitrogen and phosphates), toxic chemicals, refractory organics, heavy metal and dissolved inorganics. The report details out eight different methods – filtration, sedimentation, distillation, sand filters, flocculation, chlorination, reverse osmosis (RO), UV irradiation. For each of these methods, pros and cons are discussed and it is concluded that RO and UV methods may be the most sustainable.

NALCO Water
An Ecolab Company

Nalco Water India Private Limited
*(Formerly Nalco Water India Limited)*
S. No. 238/239, 1st Floor, Quadra 1, Panchshil,
Magarpatta Road, Sade Satra Nali,
Pune - 411 028, India.
Tel. : + 91 20 66594000
Fax : + 91 20 66594380
www.ecolab.com | www.nalco.com

Date :24th August 2023

**TO WHOMSOEVER IT MAY CONCERN**

This is to certify that **Ms Rhea Gupta**, a student of Shri Ram School Aravali (Gurgaon, India) worked under our supervision at Ecolab from January 2023 to May 2023 for a period of five months.

Rhea worked on a research document titled **"Water Treatment Methods and their Impact on Sustainability"**. She worked with two senior chemists (Shubham Patil and Ajit Unhale) from the RD&E team of Ecolab and under their guidance, identified the pollutants in water and analysed different methods of treatment and their pros and cons.

During this tenure, Rhea demonstrated very good initiative, high degree of motivation, and very good receptivity to feedback. She had a strong and diligent mindset toward research and was very motivated to achieve the right outcomes from her research. We are glad that she took the research work forward even with some field work.

We congratulate Rhea for her successful internship with us and wish her the very best for her coming years.

Anup Thakur
Sr RD&E Group Leader

# Table of Contents

# Background and context

Water is at the core and is crucial for socioeconomic development, healthy ecosystems and for human survival itself. It is very important for reducing the worldwide burden of illness and raising the health, welfare, and productivity of populations. The water business is ever-changing quickly, adapting to raised population pressure and global climate change. There's goodly pressure on business and domain to develop property water management methods and technologies. (UN, International decade for action, n.d.).

## Why is water important?

Fresh water is necessary for the survival of all living organisms on earth. Our bodies are made up of about 60% water and we cannot survive more than a few days without it. Water is a precious substance that meets our physical needs while at the same time being of great spiritual importance to many people. Water is also an integral part of many ecosystems that support us and a myriad of other species. Body uses water in all its cells, organs and tissues to help regulate its temperature and maintain other bodily functions. Because body loses water through breathing, sweating, and digestion, it is important to rehydrate by drinking fluids and eating foods that contain water. (McGill, n.d.)

## How much drinking water do we have?

When you look at a globe or a map of the Earth, it seems we have a lot of water. Water covers 72% of the earth. Unfortunately, we cannot use most of that as drinking water. Over 97% of the earth's water is salt water in oceans and seas. Another 2% is frozen in icecaps and glaciers. That leaves less than 1% of the earth's water for everyone to drink. (PennState, 2022)

## How much water should one intake?

On an average, an adult should drink at least 8-10 glasses of water daily. Generally, we get 80% of fluid from drinking water and the rest 20% from eating food. The amount of water intake also depends upon various factors, such as: (KentRO, n.d.)

- Individual Body Weight
- Activity Level: Active, moderate or sedentary
- Medical conditions
- Sweat

## What are the sources of Water?

Drinking water comes from natural sources that are either groundwater or surface water. Groundwater comes from rain and snow that seeps into the ground. The water gets stored in open spaces and pores or in layers of sand and gravel known as aquifers. We use water wells or springs to harvest this groundwater.

Surface water also comes from rain and snow. It is the water that fills the rivers, lakes, and streams. Water is pumped, both from groundwater or surface water sources, into pipes or tanks. The pipes eventually lead to our homes, schools, businesses, and any place where you can turn on the tap and drink water. (PennState, 2022)

## Should you drink pure water?

Drinking pure water helps maintain the balance of body fluids. Your body is composed of about 60% water. The functions of these bodily fluids include digestion, absorption, circulation, creation of saliva, transportation of nutrients, and maintenance of body temperature. When your water is of poor quality, your mind and body cannot function properly. You may feel sluggish, bloated and dehydrated without the proper amount of high-quality water. While public water treatment facilities remove major contaminants, they may not necessarily remove impurities that make your water smell and taste as fresh water should, and they may not be supplying you with water that is optimal for your health. Water filters provide an extra line of defense against microorganisms that may make you sick or dry out your hair and skin. (WebMD, 2022)

- Induces weight loss: Drinking water helps in losing weight. It helps body metabolism function properly. It helps to cleanse the body and flush out toxins through urine. Water can make a replacement for aerated drinks. Aerated beverages contain a lot of sugar, which adds to the body weight. Whereas water helps to curb cravings for snacks while quenching thirst and reducing weight.

- Helps fight fatigue: Two-thirds of the human body consists of water; thus, dehydration affects our energy levels. Dehydration results in fatigue and lethargy. Water helps in maintaining a healthy heart rate and blood pressure level. Our blood is 90 percent water, and blood is a carrier of oxygen. Drinking water sends oxygen to our cells and organs, thus, it helps fight fatigue. It also helps in suppressing stress hormones like cytokines, thus easing your mood.

- Strengthens immune system: Drinking pure water strengthens the immune system. Water helps in producing lymph in your body, which keeps your immune system healthy. Drinking pure water lets your body detoxify through urination, thus keeping the body toxin-free and with a strong immune system.

- Brings glow on your face: Drinking an adequate amount of water reduces fine lines and wrinkles on your face. Intake of pure water boosts skin cells which brings a glow on your face. Drinking water will keep the skin hydrated and regularize blood flow.
- Gives life to kidneys: The kidney regulates blood pressure, maintains the water level in the body and filters waste. Drinking pure water helps kidneys to perform effectively. The habit of drinking pure water in adequate quantity also protects against the formation of kidney stones.
- Lubricates joints: The practice of drinking water protects joints from any damage. Our bone cartilage has 80 percent water. Cartilage is found in joints and spinal disks. Thus, dehydration can reduce the shock absorbing quality of joints, which can result in brittle bones and lifelong joint pain. (KentRO, n.d.)
- Others:
  - Properly digests food and absorb nutrients from food
  - Helps in healthy, glowing skin
  - Decreases muscle and joint inflammation
  - Enables better circulation
  - Detoxifies your body naturally

## Impact of poor water on health

Contaminated water and poor sanitation are linked to transmission of diseases such as cholera, diarrhea, dysentery, hepatitis A, typhoid and polio. Absent, inadequate, or inappropriately managed water and sanitation services expose individuals to preventable health risks. This is particularly the case in health care facilities where both patients and staff are placed at additional risk of infection and disease when water, sanitation and hygiene services are lacking. Globally, 15% of patients develop an infection during a hospital stay, with the proportion much greater in low-income countries.

Inadequate management of urban, industrial and agricultural waste water means that drinking water of hundreds of millions of people is dangerously contaminated or chemically polluted. Natural presence of chemicals, particularly in groundwater, can also be of health significance, including arsenic and fluoride, while other chemicals, such as lead, may be elevated in drinking water as a result of leaching from water supply components in contact with drinking water.

Some 829,000 people are estimated to die each year from diarrhea as a result of unsafe drinking water, sanitation and hand hygiene. Yet diarrhea is largely preventable, and the deaths of 297,000 children aged under 5 years could be avoided each year if these risk factors were addressed. Where water is not readily available, people may decide handwashing is not a priority, thereby adding to the likelihood of diarrhea and other diseases.

Diarrhea is the most widely known disease linked to contaminated food and water but there are other hazards. In 2017, over 220 million people required preventative treatment for schistosomiasis – an acute and chronic disease caused by parasitic worms contracted through exposure to infested water.

In many parts of the world, insects that live or breed in water carry and transmit diseases such as dengue fever. Some of these insects, known as vectors, breed in clean, rather than dirty water, and household drinking water containers can serve as breeding grounds. The simple intervention of covering water storage containers can reduce vector breeding and may also reduce faecal contamination of water at the household level. (WHO, Drinking Water, 2022)

# Water Pollution and Standards

## Potential Pollutants in water

- Suspended solids (fly ash, saw dust, cement dust, other particulate matter)
- Biodegradable organics (proteins, carbohydrates and fats)
- Pathogens (bacteria, virus, protozoa, helminths)
- Nutrients (Nitrogen, Phosphorus and Carbon)
- Priority pollutants (highly toxic chemicals such as Arsenic, Asbestos, Barium, Beryllium, Selenium, Silver)
- Refractory organics (pesticides, phenols, surfactants)
- Heavy metals (Cadmium, Chromium, Lead, Mercury, Nickel, Tin)
- Dissolved inorganics (nuisance chemicals)

## Water treatment

Water treatment is the process of removing undesirable chemicals, biological contaminants, suspended solids and gases from contaminated water. The goal of this process is to produce water fit for a specific purpose. Most water is disinfected for human consumption (drinking water) but water treatment may also be designed for a variety of other purposes, including meeting the requirements of medical, pharmacological, chemical and industrial applications. In general, the methods used include physical processes such as filtration, sedimentation, and distillation, biological processes such as slow sand filters or biologically active carbon, chemical processes such as flocculation and chlorination and the use of electromagnetic radiation such as ultraviolet light.

The treatment process of water may reduce the concentration of particulate matter including suspended particles, parasites, bacteria, algae, viruses, fungi; and a range of dissolved and particulate material derived from the surfaces that water may have made contact with after falling as rain. (Ecologix, n.d.)

## Water Quality Standards

The standards for drinking water quality are typically set by governments or by international standards. These standards will typically set minimum and maximum concentrations of contaminants for the use that is to be made of the water.

### Central Pollution Control Board – Best use water quality criteria

| Designated Best-Use class of water criteria | Class of water | Criteria |
|---|---|---|
| Drinking Water Source without conventional treatment but after disinfection | A | Total Coliforms Organism MPN/100ml shall be 50 or less<br>pH between 6.5 and 8.5<br>Dissolved Oxygen 6mg/l or more<br>Biochemical Oxygen Demand 5 days 20C 2mg/l or less |
| Outdoor bathing (Organized) | B | Total Coliforms Organism MPN/100ml shall be 500 or less pH between 6.5 and 8.5 Dissolved Oxygen 5mg/l or more<br>Biochemical Oxygen Demand 5 days 20C 3mg/l or less |
| Drinking water source after conventional treatment and disinfection | C | Total Coliforms Organism MPN/100ml shall be 5000 or less pH between 6 to 9 Dissolved Oxygen 4mg/l or more<br>Biochemical Oxygen Demand 5 days 20C 3mg/l or less |
| Propagation of Wildlife and Fisheries | D | pH between 6.5 to 8.5 Dissolved Oxygen 4mg/l or more<br>Free Ammonia (as N) 1.2 mg/l or less |
| Irrigation, Industrial Cooling, Controlled Waste disposal | E | pH between 6.0 to 8.5<br>Electrical Conductivity at 25C micro mhos/cm Max.2250<br>Sodium absorption Ratio Max. 26<br>Boron Max. 2mg/l |
| | Below E | Not Meeting A, B, C, D & E Criteria |

(CPCB, n.d.)

### Indian Drinking Water – Specification

As per the IS 10500:2012 (CGWB, 2012), the limits of major physicochemical and microbial contaminants are as follows:

| Test parameter | Acceptable limit | Permissible limit (In the absence of an alternate source of water) |
|---|---|---|
| **pH value** | 6.5-8.5 | No Relaxation |
| **Turbidity** | 1 | 5 |
| **Total hardness as CaCO3, mg/l, Max** | 200 | 600 |
| **E. coli presence/ absence** | Shall not be detectable in any 100 ml sample | Shall not be detectable in any 100ml sample |
| **Total iron as Fe, mg/l, Max** | 0.3 | No Relaxation |
| **Taste** | Agreeable | Agreeable |
| **Odor** | Agreeable | Agreeable |

## Water Quality Parameters

### Physical

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **Electrical conductivity** | Measures the degree to which a sample of water or similar solution can carry or conduct an electric current<br>Conductivity can indicate groundwater seepage or sewage leakage.<br>Detect levels of water contamination when measuring the conductivity of water<br>A high conductivity means that the water contains a lot of contaminants | Less rain or low addition of fresh water | - |

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **Salinity** | Measure of the dissolved salts in the water<br>Dissolved ions increase both salinity and conductivity | Accumulation of salt from rainfall over many thousands of years or from the weathering of rocks | RO, Filtration, Distillation |
| **Solids** | Dissolved solid may be organic (animal or plants waste) or inorganic compounds (carbonate, sulfate, bicarbonate etc).<br>These compounds give variety of effects like hardness, taste, odor etc depending on nature of dissolved solid<br>If the dissolved solid in water exceeds 300 mg/ ltr, it adversely affects living organisms as well as industrial products | Soil erosion, waste discharge, runoff, or changes in ecological communities including algal growth or abundance of benthic organisms | Sedimentation, Microporous basic filtration, Centrifugation |
| **Turbidity** | Degree of cloudiness of water.<br>Turbidity meter or sensor are designed to measure the ability of light to have to pass through the water<br>High levels of particulate matter can act as a barrier to harmful microorganisms, which makes it more difficult to remove these contaminants; Suspended material can damage fish gills, reduce growth rates, and lower resistance to disease | Melting glaciers, sawdust, wood ashes or chemicals in the water | Coagulation, flocculation, Ultrafiltration, RO |
| **Temperature** | Some aspects of water quality that are affected by water temperature include odor, chemical reactions, dissolved oxygen levels, palatability and viscosity.<br>Biological oxygen demand, sedimentation and chlorination all depend on the temperature of the water. | Water depth, flow velocity, and snowmelt | - |
| **Color** | Decaying organic matter may change the color of the water, which includes mainly vegetation. Inorganic materials such as rocks, soil and stones can also affect the color of water | Presence of minerals | Activated Carbon, RO, Adsorption, Filtration |
| **Taste and odor** | The taste of water may change and produce an odor as a result of foreign substances being introduced into the water. Such substances can include organic materials, dissolved gases and inorganic compounds. Most of such substances come from agricultural, natural, and domestic sources | Biological degradation or decomposition of organics | Adsorption, Chlorination, |

## Chemical

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **pH** | pH values can range from 0-14.<br>Reading of 7.0 means that the water is neutral.<br>Any reading below 7.0 is acidic, and any reading above 7.0 is alkaline.<br>Pure water has a neutral pH.<br>However, rainfall is more acidic and usually has a pH of 5.6. Water is considered safe to drink if it has a pH of 6.5 to 8.5. | Photosynthesis, respiration, and decomposition | Adding Soda ash/ Sodium hydroxide |
| **Acidity** | This is a measure of how much acid is present in a given solution.<br>The acidity of water is the quantitative ability to neutralize a base at a given pH.<br>Acidity is usually caused by the presence of inorganic acids, hydrolytic salts and carbon dioxide. | Weathering of soils, production of dissolved organic carbon from decaying vegetation, input of marine aerosols, dilution by rainwater or snowmelt, oxidation of previously reduced sulfur and nitrogen, and acid rain (largely sulfur and nitrogen related) | Adding Sodium Carbonate |
| **Alkalinity** | Alkalinity indicates the ability of water to neutralize acids.<br>Probably the most common reason for measuring the alkalinity of a water sample is to determine how much soda and lime must be added to the water in order to soften it.<br>The water softening process is particularly beneficial in reducing boiler corrosion. | Acid, rain, plastic, and the alkalinity of natural water is determined by the soil and bedrock through which it passes | Adding Sodium Hydroxide |
| **Hardness** | Hardness occurs when water has a high mineral content.<br>Dissolved minerals in the water may form scale on the hot water pipes.<br>The hardness of water is mainly caused by the presence of magnesium and calcium ions,<br>groundwater has a higher hardness than surface water. | Weathering of rocks and soil | Ion-Exchange, RO, adding slaked lime or washing soda |

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **Chlorine** | Although chlorine does not occur naturally in water, it is often added to wastewater for disinfection.<br>Although alkaline chlorine is a toxic gas, its aqueous solution is completely harmless to humans. If small amounts of chlorine are found in the water, it is an indication that the water is clean and essentially free of contaminants. | - | - |
| **Dissolved oxygen** | One of the key water quality parameters that can help determine the level of pollution in rivers, lakes and streams.<br>high concentration of dissolved oxygen in the water ensures water quality is high. Dissolved oxygen is produced due to the solubility of oxygen.<br>The amount of dissolved oxygen in water depends on many factors, not the least of which are the salinity of the water, the pressure and the temperature. | Cold water can hold more dissolved oxygen than warm water. In winter and early spring, when the water temperature is low, the dissolved oxygen concentration is high | Supplementing wind and wave action |
| **Biological oxygen demand** | Microorganisms like bacteria use organic matter as a food source. When this material is metabolized, oxygen is consumed. If this process occurs in water, the dissolved oxygen in the water sample will be consumed.<br>If a large amount of organic matter is present in the water, a large amount of dissolved oxygen will be consumed to ensure that the organic matter decomposes. This can create problems because aquatic plants and animals need dissolved oxygen to survive. If the biological oxygen demand level is high, the water is contaminated. | - | Coagulation & Flocculation |

## Biological

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **Bacteria** | Single-celled plants that can ingest food and multiply rapidly if the pH of the water, food supply and temperature are ideal.<br>Bacteria can grow quickly; hence it is almost impossible to count the number of bacteria in a water sample.<br>In most cases, bacteria will multiply at a slower rate in colder water. High levels of bacteria in water can lead to many harmful waterborne diseases, including cholera, tularemia and typhoid. | Surrounding soil | Ultraviolet (UV) Radiation |
| **Algae** | Tiny, microscopic plants composed of photosynthetic pigments.<br>These plants are able to sustain life by efficiently converting inorganic material into organic material, which is done using energy from the sun.<br>In this process, algae consume carbon dioxide and release oxygen. Algae are also essential in the treatment of wastewater using stabilization ponds.<br>Major problems caused by algae include strange odors and poor taste problems.<br>certain species of algae can pose a serious public health risk. For example, blue-green algae have the potential to kill cattle. | Increased nutrients, warmer temperature, abundant light, and stable wind conditions | Chlorination, Filtration |
| **Nutrients** | Naturally occurring nutrient found in fresh and salt water.<br>Essential for plant growth in aquatic ecosystems.<br>Problems arise when large amounts of nitrogen are introduced into river ecosystems and as a result, excessive algal growth may occur, depleting the available oxygen in streams on which fish and other aquatic life depend. | Wastewater treatment plants, farmland fertilizer, animal manure runoff, septic systems, and industrial discharge | Anammox and denitrification |

| Parameter | Description | Environment condition effecting | Suitable Method |
|---|---|---|---|
| **Viruses** | Viruses are tiny biological structures that may be harmful to human health. Only a powerful electron microscope can see viruses.<br>All viruses need a parasite to survive. Because viruses are small, they are able to pass through most filters.<br>Certain waterborne viruses can cause hepatitis and similar health problems. Despite the difficulty of dealing with viruses, most water treatment facilities should be able to eliminate them during the disinfection process. | Soil surrounding, temprature | Ultraviolet (UV) Radiation |

(FAO, n.d.) (Apure, 2022) (Sensorex, n.d.)Water Treatment

## Pre-treatment

- Pumping and containment – The majority of water must be pumped from its source or directed into pipes or holding tanks. To avoid adding contaminants to the water, this physical infrastructure must be made from appropriate materials and constructed so that accidental contamination does not occur.
- Screening – The first step in purifying surface water is to remove large debris such as sticks, leaves, rubbish and other large particles which may interfere with subsequent treatment steps. Most deep groundwater does not need screening before other treatment steps.
- Storage – Water from rivers may also be stored in bankside reservoirs for periods between a few days and many months to allow natural biological treatment to take place. This is especially important if treatment is by slow sand filters. Storage reservoirs also provide a buffer against short periods of drought or to allow water supply to be maintained during transitory pollution incidents in the source river.

Widely varied techniques are available to remove the fine solids, micro-organisms and some dissolved inorganic and organic materials. The choice of method will depend on the quality of the water being treated, the cost of the treatment process and the quality standards expected of the processed water. (Ecologix, n.d.)

## Water Treatment Process

The treatment process below is conventionally used in municipal water treatment plants. Municipal water treatment may include additional processes or variations depending on the scale of the operation and quality of the raw (source) water.

**Coagulation**

Coagulation is often the first step in water treatment. During coagulation, chemicals with a positive charge are added to the water. The positive charge neutralizes the negative charge of dirt and other dissolved particles in the water. When this occurs, the particles bind with the chemicals to form slightly larger particles. Common chemicals used in this step include specific types of salts, aluminum, or iron

**Flocculation**

Flocculation follows the coagulation step. Flocculation is the gentle mixing of the water to form larger, heavier particles called flocs. Often, water treatment plants will add additional chemicals during this step to help the flocs form.

**Sedimentation**

Sedimentation is one of the steps water treatment plants use to separate out solids from the water. During sedimentation, flocs settle to the bottom of the water because they are heavier than water.

**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.

**Disinfection**

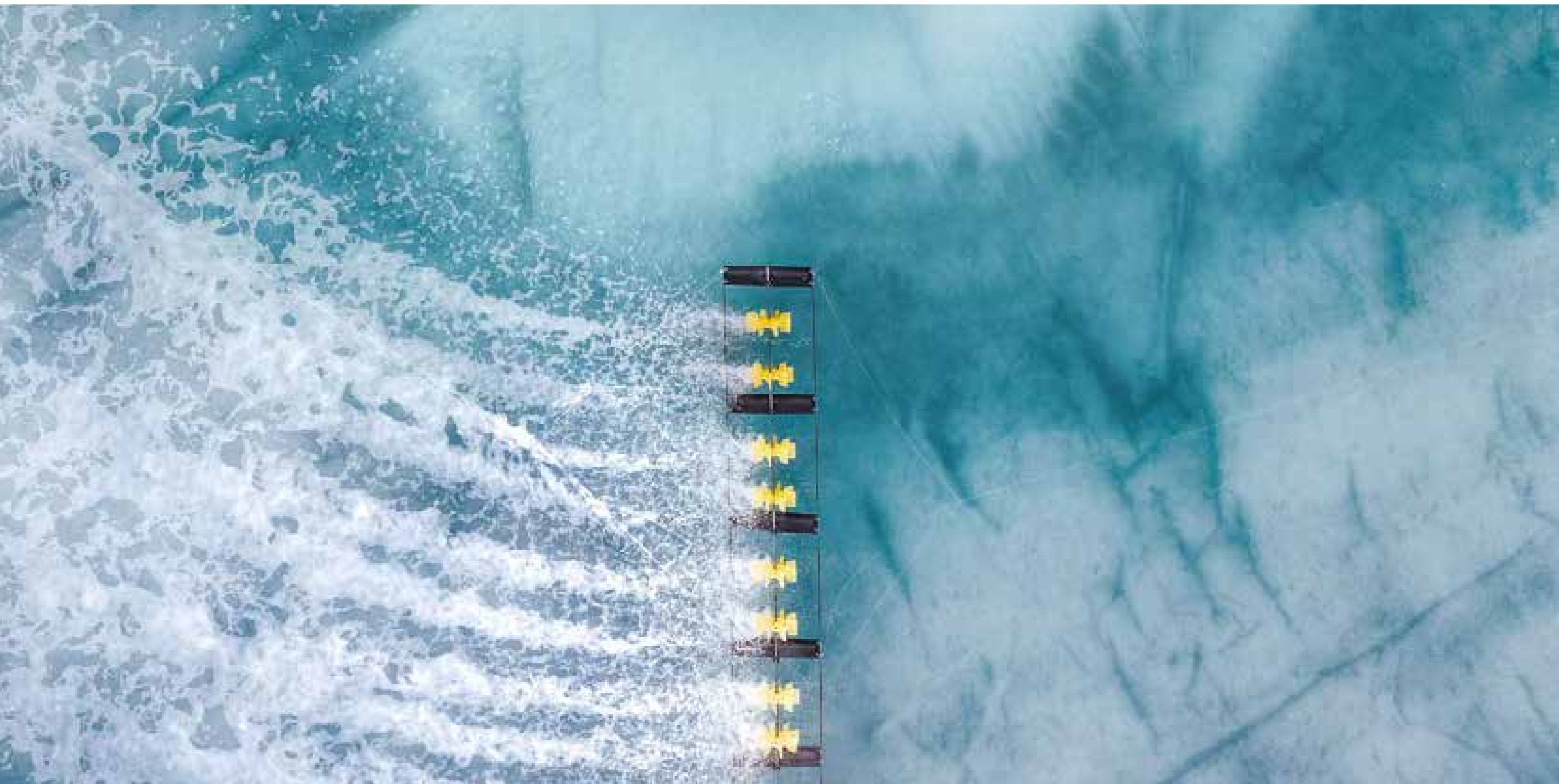
After the water has been filtered, water treatment plants may add one or more chemical disinfectants (such as chlorine, chloramine, or chlorine dioxide) to kill any remaining parasites, bacteria, or viruses. To help keep water safe as it travels to homes and businesses, water treatment plants will make sure the water has low levels of the chemical disinfectant when it leaves the treatment plant. This remaining disinfectant kills germs living in the pipes between the water treatment plant and your tap.

# Common water Treatment Methods

## Distillation

| Method of Treatment | Process |
|---|---|
| **Distillation** | Water is first heated to boiling. The water vapor rises to a condenser where cooling water lowers the temperature, so the vapor is condensed, collected and stored. Most contaminants remain behind in the liquid phase vessel. However, there can sometimes be what is called carry-overs in the water that is distilled. Organics such as herbicides and pesticides, with boiling points lower than 100 °C cannot be removed efficiently and can actually become concentrated in the product water |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Removes a broad range of contaminants**<br>**Reusable** | Some contaminants can be carried into the condensate<br>Requires careful maintenance to ensure purity<br>Consumes large amounts of energy<br>System usually takes a large space on counter<br>Costly | Traditional method, not used widely<br>Lower applications |



## Ion Exchange

| Method of Treatment | Process |
|---|---|
| **Ion Exchange** | The ion exchange process percolates water through bead-like spherical resin materials (ion-exchange resins). Ions in the water are exchanged for other ions fixed to the beads. The two most common ion-exchange methods are softening and deionization.<br>Softening is used primarily as a pretreatment method to reduce water hardness prior to reverse osmosis (RO) processing. The softeners contain beads that exchange two sodium ions for every calcium or magnesium ion removed from the "softened" water.<br>Deionization (DI) beads exchange either hydrogen ions for cations or hydroxyl ions for anions.<br>The cation exchange resins, made of styrene and divinylbenzene containing sulfonic acid groups, will exchange a hydrogen ion for any cations they encounter (e.g., $Na^+$, $Ca^{++}$, $Al^{+++}$).<br>Similarly, the anion exchange resins, made of styrene and containing quaternary ammonium groups, will exchange a hydroxyl ion for any anions (e.g., $Cl^-$). The hydrogen ion from the cation exchanger unites with the hydroxyl ion of the anion exchanger to form pure water<br>These resins may be packaged in separate bed exchangers with separate units for the cation and anion exchange beds. Or they may be packed in mixed bed exchangers containing a mixture of both types of resins. In either case, the resin must be "regenerated" once it has exchanged all its hydrogen and/or hydroxyl ions for charged contaminants in the water.<br>This regeneration reverses the treatment process, replacing the contaminants bound to the DI resins with hydrogen and hydroxyl ions |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Removes dissolved inorganics effectively**<br>**Regenerable (service deionization)**<br>**Relatively inexpensive initial capital investment** | Does not effectively remove particles, pyrogens or bacteria<br>DI (Deionization) beads can generate resin particles and culture bacteria<br>High operating costs over long-term | Widely used in household filters to produce soft water |

## Carbon Adsorption

| Method of Treatment | Process |
|---|---|
| **Carbon Adsorption** | Carbon absorption is a widely used method of home water filter treatment because of its ability to improve water by removing disagreeable tastes and odors, including objectionable chlorine. Activated carbon effectively removes many chemicals and gases, and in some cases, it can be effective against microorganisms. However, generally it will not affect total dissolved solids, hardness, or heavy metals. Only a few carbon filter systems have been certified for the removal of lead, asbestos, cysts, and coliform.<br><br>There are two types of carbon filter systems, each with advantages and disadvantages: granular activated carbon, and solid block carbon. These two methods can also work along with a reverse osmosis system, which can be read about below.<br><br>Activated carbon is created from a variety of carbon-based materials in a high-temperature process that creates a matrix of millions of microscopic pores and crevices. One pound of activated carbon provides anywhere from 60 to 150 acres of surface area. The pores trap microscopic particles and large organic molecules, while the activated surface areas cling to, or adsorb, small organic molecules. The ability of an activated carbon filter to remove certain microorganisms and certain organic chemicals, especially pesticides, THMs (the chlorine by-product), trichloroethylene (TCE), and PCBs, depends upon several factors, such as the type of carbon and the amount used, the design of the filter and the rate of water flow, how long the filter has been in use, and the types of impurities the filter has previously removed.<br><br>The carbon adsorption process is controlled by the diameter of the pores in the carbon filter and by the diffusion rate of organic molecules through the pores. The rate of adsorption is a function of the molecular weight and the molecular size of the organics. Certain granular carbons effectively remove chloramines. Carbon also removes free chlorine and protects other treatment media in the system that may be sensitive to an oxidant such as chlorine.<br><br>Carbon is usually used in combination with other treatment processes. The placement of carbon in relation to other components is an important consideration in the design of a water treatment system. |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Removes dissolved organics and chlorine effectively**<br><br>**Long life (high capacity)** | Can generate carbon fines | Widely used in residential for ground water treatment |

### Microporous Basic Filtration

| Method of Treatment | Process |
| --- | --- |
| **Microporous Basic Filtration** | There are three types of microporous filtration: depth, screen, and surface. Depth filters are matted fibers or materials compressed to form a matrix that retains particles by random adsorption or entrapment. Screen filters are inherently uniform structures which, like a sieve, retain all particles larger than the precisely controlled pore size on their surface. Surface filters are made from multiple layers of media. When fluid passes through the filter, particles larger than the spaces within the filter matrix are retained, accumulating primarily on the surface of the filter<br>The distinction between filters is important because the three serve very different functions. Depth filters are usually used as prefilters because they are an economical way to remove 98% of suspended solids and protect elements downstream from fouling or clogging<br>Surface filters remove 99.99% of suspended solids and may be used as either prefilters or clarifying filters. Microporous membrane (screen) filters are placed at the last possible point in a system to remove the last remaining traces of resin fragments, carbon fines, colloidal particles and microorganisms |

| Advantages | Disadvantages | Application |
| --- | --- | --- |
| **Absolute filters remove all particles and microorganisms greater than the pore size**<br>**Requires minimal maintenance** | Will not remove dissolved inorganics, chemicals, pyrogens or all colloidals<br>Potentially high expendable costs<br>Not regenerable | Treatment of portable water supply |

### Ultrafiltration

| Method of Treatment | Process |
| --- | --- |
| **Ultrafiltration** | A microporous membrane filter removes particles according to pore size. By contrast, an ultrafiltration (UF) membrane functions as a molecular sieve. It separates dissolved molecules on the basis of size by passing a solution through an infinitesimally fine filter. The ultrafilter is a tough, thin, selectively permeable membrane that retains most macromolecules above a certain size including colloids, microorganisms, and pyrogens. Smaller molecules, such as solvents and ionized contaminants, are allowed to pass into the filtrate. Thus, UF provides a retained fraction (retentate) that is rich in large molecules and a filtrate that contains few, if any, of these molecules.<br>Ultrafilters are available in several selective ranges. In all cases, the membranes will retain most, but not necessarily all, molecules above their rated size. |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Effectively removes most particles, pyrogens, microorganisms, and colloids above their rated size**<br>**Produces highest quality water for least amount of energy**<br>**Regenerable** | Will not remove dissolved inorganics | Waste water treatment, employ ultrafiltration in order to recycle flow or add value to later products. |

### Reverse Osmosis (RO)

| Method of Treatment | Process |
|---|---|
| **Reverse Osmosis (RO)** | Reverse osmosis (RO) is the most economical method of removing 90% to 99% of all contaminants. The pore structure of RO membranes is much tighter than UF membranes. RO membranes are capable of rejecting practically all particles, bacteria and organics>300 Daltons molecular weight (including pyrogens). In fact, reverse osmosis technology is used by most leading water bottling plants. Natural osmosis occurs when solutions with two different concentrations are separated by a semi-permeable membrane. Osmotic pressure drives water through the membrane; the water dilutes the more concentrated solution; and the end result is an equilibrium.<br>In water treatment systems, hydraulic pressure is applied to the concentrated solution to counter act the osmotic pressure. Pure water is driven from the concentrated solution and collected downstream of the membrane. Because RO membranes are very restrictive, they yield slow flow rates. Storage tanks are required to produce an adequate volume in a reasonable amount of time.<br>RO also involves an ionic exclusion process. Only solvent is allowed to pass through the semi-permeable RO membrane, while virtually all ions and dissolved molecules are retained (including salts and sugars).<br>The semi-permeable membrane rejects salts (ions) by a charge phenomena action: the greater the charge, the greater the rejection. Therefore, the membrane rejects nearly all (>99%) strongly ionized polyvalent ions but only 95% of the weakly ionized monovalent ions like sodium.<br>Reverse osmosis is highly effective in removing several impurities from water such as total dissolved solids (TDS), turbidity, asbestos, lead and other toxic heavy metals, radium, and many dissolved organics. The process will also remove chlorinated pesticides and most heavier weight VOCs.<br>Reverse osmosis and activated carbon filtration are complementary processes. Combining them results in the most effective treatment against the broadest range of water impurities and contaminants. RO is the most economical and efficient method for purifying tap water if the system is properly designed for the feed water conditions and the intended use of the product water.RO is also the optimum pretreatment for reagent-grade water polishing systems.<br>In addition, reverse osmosis treatment is an insurance policy against nuclear radiation such as radioactive plutonium or strontium in the drinking water. If one lives near a nuclear power plant, this is a key way to ensure the household is drinking the best water for their health. |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Effectively removes most particles, pyrogens, microorganisms, and colloids above their rated size**<br>**Produces highest quality water for least amount of energy**<br>**Regenerable** | Will not remove dissolved inorganics | Mostly used in household and commercial water treatment<br>Treatment of surface and ground water |

## Factors Affecting RO Membrane Performance

| Factors Affecting RO Membrane Performance | |
|---|---|
| **Effect of pressure** | Feedwater pressure affects both the water flux and salt rejection of RO membranes. Osmosis is the flow of water across a membrane from the dilute side toward the concentrated solution side. Reverse osmosis technology involves application of pressure to the feedwater stream to overcome the natural osmotic pressure. Pressure in excess of the osmotic pressure is applied to the concentrated solution and the flow of water is reversed. A portion of the feedwater (concentrated solution) is forced through the membrane to emerge as purified product water of the dilute solution side.<br>Water flux across the membrane increases in direct relationship to increases in feedwater pressure. Increased feedwater pressure also results in increased salt rejection but the relationship is less direct than for water flux.<br>Because RO membranes are imperfect barriers to dissolved salts in feedwater, there is always some salt passage through the membrane. As feedwater pressure is increased, this salt passage is increasingly overcome as water is pushed through the membrane at a faster rate than salt can be transported. |
| **Effect of temperature** | Membrane productivity is very sensitive to changes in feedwater temperature. As water temperature increases, water flux increases almost linearly, due primarily to the higher diffusion rate of water through the membrane.<br>Increased feedwater temperature also results in lower salt rejection or higher salt passage. This is due to a higher diffusion rate for salt through the membrane.<br>The ability of a membrane to tolerate elevated temperatures increases operating latitude and is also important during cleaning operations because it permits use of stronger, faster cleaning processes. |
| **Effect of salt concentration** | Osmotic pressure is a function of the type and concentration of salts or organics contained in feedwater. As salt concentration increases, so does osmotic pressure. The amount of feedwater driving pressure necessary to reverse the natural direction of osmotic flow is, therefore, largely determined by the level of salts in the feedwater. If feed pressure remains constant, higher salt concentration results in lower membrane water flux. The increasing osmotic pressure offsets the feedwater driving pressure. |

| Factors Affecting RO Membrane Performance | |
|---|---|
| **Effect of recovery** | Reverse osmosis occurs when the natural osmotic flow between a dilute solution and a concentrated solution is reversed through application of feedwater pressure. If percentage recovery is increased (and feedwater pressure remains constant), the salts in the residual feed become more concentrated and the natural osmotic pressure will increase until it is as high as the applied feed pressure. This can negate the driving effect of feed pressure, slowing or halting the reverse osmosis process and causing permeate flux and salt rejection to decrease and even stop.<br><br>The maximum percent recovery possible in any RO system usually depends not on a limiting osmotic pressure, but on the concentration of salts present in the feedwater and their tendency to precipitate on the membrane surface as mineral scale. The most common sparingly soluble salts are calcium carbonate (limestone), calcium sulfate (gypsum), and silica. Chemical treatment of feedwater can be used to inhibit mineral scaling. |
| **Effect of pH** | The pH tolerance of various types of RO membranes can vary widely. Thin-film composite (TF) membranes are typically stable over a broader pH range than cellulose acetate (CA) membranes and, therefore, offer greater operating latitude.<br><br>Membrane salt rejection performance depends on pH. Water flux may also be affected. Water flux and salt rejection for thin film membranes are essentially stable over a broad pH range.<br><br>The stability of TF membrane over a broad pH range permits stronger, faster, and more effective cleaning procedures to be used compared to CA membranes |

## Ultraviolet (UV) Radiation

| Method of Treatment | Process |
|---|---|
| **Ultraviolet (UV) Radiation** | Ultraviolet radiation has widely been used as a germicidal treatment for water. Mercury low pressure lamps generating 254 nm UV light are an effective means of sanitizing water. The adsorption of UV light by the DNA and proteins in the microbial cell results in the inactivation of the microorganism. Recent advances in UV lamp technology have resulted in the production of special lamps which generate both 185 nm and 254 nm UV light. This combination of wavelengths is necessary for the photooxidation of organic compounds. With these special lamps, Total Organic Carbon (TOC) levels in high purity water can be reduced to 5 ppb. |

| Advantages | Disadvantages | Application |
|---|---|---|
| **Effective sanitizing treatment**<br><br>**Oxidation of organic compounds (185 nm and 254 nm) to < 5 ppb TOC** | Decreases resistivity<br><br>Will not remove particles, colloids, or ions | Disinfecting bacteria, virus, and cysts from the water. |

# Sustainability and impact on treatment methods

## Treatment: A priority over Sustainability?

Sustainable water management means the ability to meet the water needs of the present without compromising the ability of future generations to do the same. Achieving sustainable water management requires a multidisciplinary and holistic approach in which technical, environmental, economic, landscape, aesthetic, societal and cultural issues are addressed.

On a global scale, having sustainable water means to provide each person on the planet with affordable access to the minimum 20 to 50 litres of daily water required to sustain life. Water sustainability also means effective and holistic management of water resources. There are now multiple demands on water resources, which drive the need for sustainable, integrated and holistic water management.

**UK regulator Ofwat describes ‘Sustainable water’ as: “A sustainable water cycle in which we are able to meet our needs for water and sewerage services while enabling future generations to meet their own needs.”**

For water utilities, this can mean effective planning for water and wastewater systems to manage their operations and infrastructure and ensure the sustainability of the communities they serve

The benefits of considering sustainability during infrastructure planning include:

- Optimising environmental, economic, and social benefits by setting goals and selecting projects through a transparent and inclusive process with the community
- Realising consistency across a range of alternatives that address both utility and community goals and
- Enhancing the long-term technical, financial, and managerial capacity of the utility.
- Typically, water utilities have a long-term planning horizon and long-term infrastructure operation and maintenance commitments. (Tech, 2019)

## Sustainable Development Goals

With an “aim to transform the world”, the SDG are a call to action to end poverty and inequality, protect the planet, and ensure that all people enjoy health, justice and prosperity. (WHO, n.d.)


## SDG 6

**Ensure availability and sustainable management of water and sanitation for all.**

“Clean water is a basic human need, and one that should be easily accessible to all. There is sufficient fresh water on the planet to achieve this. However, due to poor infrastructure, investment and planning, every year millions of people — most of them children — die from diseases associated with inadequate water supply, sanitation and hygiene”. (Tracker, n.d.)

Water and sanitation are at the core of sustainable development, and the range of services they provide underpin poverty reduction, economic growth and environmental sustainability. However, in recent decades overexploitation, pollution, and climate change have led to severe water stress in locales across the world.

Today, 2.2 billion people lack access to safely managed drinking water, and more than 4.2 billion people lack safely managed sanitation. Climate change is exacerbating the situation, with increasing disasters such as floods and droughts. 80 per cent of wastewater in the world flows back into the ecosystem without being treated or reused, and 70 per cent of the world's natural wetland extent has been lost, including a significant loss of freshwater species.

The COVID-19 pandemic poses an additional impediment, impairing access for billions of people to safely managed drinking water, sanitation and hygiene services – services desperately needed to prevent the virus from spreading. Now more than ever the world needs to transform the way it manages its water resources and delivers water and sanitation services for billions of people. Urgent action is needed to overcome this global crisis, as it is affecting all countries around the world, socially, economically and environmentally.

Sustainable Development Goal 6 (SDG 6) on water and sanitation, adopted by United Nations Member States at the 2015 UN Summit as part of the 2030 Agenda for Sustainable Development, provides the blueprint for ensuring availability and sustainable management of water and sanitation for all. As a direct response to the Decade of Action and Delivery for Sustainable Development called for by Heads of State and Government at the SDG Summit in 2019, the UN system launched the SDG 6 Global Acceleration Framework in July 2020, to step up progress towards the Sustainable Development Goals and put the world on track to realize their targets by 2030. We call upon all stakeholders to galvanize actions around the framework in order to accelerate achievement of the water-related goals and targets and overcome the global crisis. (UN, Water and Sanitation, n.d.)

## Global: Facts and Figures

- In 2020, 74 per cent of the global population had access to safely managed drinking water services, up from 70 per cent in 2015. Still, two billion people live without safely managed drinking water services, including 1.2 billion people lacking even a basic level of service, in 2020.
- Between 2015 and 2020, the population with safely managed sanitation increased from 47 per cent to 54 per cent and the population with access to handwashing facilities with soap and water in the home increased from 67 per cent to 71 per cent. Rates of progress for these basic services would need to quadruple for universal coverage to be reached by 2030.
- At the current rates of progress, 1.6 billion people will lack safely managed drinking water, 2.8 billion people will lack safely managed sanitation, and 1.9 billion people will lack basic hand hygiene facilities in 2030.
- Eight out of 10 people who lack even basic drinking water service live in rural areas, and about half of them live in least developed countries (LDCs).
- Water use efficiency worldwide rose from $17.4 per cubic metre in 2015 to $19.4 per cubic metre in 2019, a 12 per cent efficiency increase.
- Assessment of rivers, lakes and aquifers in 97 countries in 2020 shows that 60 per cent of water bodies have good water quality. For at least 3 billion people, the quality of the water they rely upon is unknown owing to a lack of monitoring.
- From 2015 to 2020, the population practising open defecation decreased by a third, from 739 million people to 494 million. The world is on track to eliminate open defecation by 2030.
- Over the past 300 years, over 85 per cent of the planet's wetlands have been lost, mainly through drainage and land conversion, with many remaining wetland areas degraded. Since 1970, 81 per cent of species dependent on inland wetlands have declined faster than those relying on other biomes, and an increasing number of these species are facing extinction.
- Across the world, water stress levels remained safe at 18.6 per cent in 2019. However, Southern Asia and Central Asia registered high levels of water stress at over 75 per cent, whereas Northern Africa registered a critical water stress level of over 100 per cent. Since 2015, water stress levels have increased significantly in Western Asia and Northern Africa.
- Data from 2017 and 2020 suggest only 32 countries have 90 per cent or more of their transboundary waters covered by cross-border cooperative arrangements. (UN, Goal 6: Ensure access to water and sanitation for all, n.d.)

## How different water sources can be used sustainably?

- Surface water: Limited as is unequally distributed around the world and pollution from various activities means that surface water without treatment is not suitable for drinking. If properly constructed, dams can provide a sustainable water supply as the structures can be used for power generation, irrigation, flood prevention, water diversion and navigation. However, large-scale dam projects may present challenges to sustainability: negative environmental impacts on wildlife habitats, fish migration, water flow and quality and socioeconomic impacts. Therefore, a sustainability impact assessment should be performed.
- Groundwater: Accounts for more than 50 per cent of global freshwater and is critical for potable water. Groundwater can be a sustainable supply of water only if the amount of water entering, leaving and being stored in the system is conserved. The IWA says unsustainable groundwater use results in water-level decline, reduce streamflow and low quality water, directly impacting local communities. (Tech, 2019)

## Exploring sustainable water treatment solutions

"For a treatment method to be sustainable, it should have less impact on the environment, have little to no carbon footprint, and be accessible to every community"

Today, it is no longer enough for water treatment plants to meet minimum health and safety requirements for drinking water and wastewater quality. To be truly sustainable, utilities must consider their carbon footprint, impact on the environment and increasing access to underserved communities. Choosing the right water treatment solutions plays a key role in this.

In general, water treatment methods can be separated into physical, biological, chemical, and physico-chemical methods. Physical methods are separation of solid impurities and coarse and fine particles from water using techniques such as screening, filtration, centrifugation, flotation, and membrane technologies. Biological methods are based on microorganisms that consume the pollutants in the water in order to maintain their vital activity. Chemical treatment implies conducting chemical reactions with pollutants – for example oxidation, reduction, or precipitation – to achieve the desired effect. Physico-chemical water treatment combines both chemical and physical treatment, for example chemical coagulation and flocculation followed by a separation step.

Chemical treatment is a well-established, safe, and effective process suitable for removing a wide variety of contaminants from water. Moreover, it is very cost and energy efficient compared to other methods. (Kemira, n.d.)

## Water treatment technologies

Water treatment technologies go hand-in-hand with the water management strategies, in which the sustainable strategies include 'Production', 'Reuse and recycle', and 'Protection'.

- Production refers to using natural resources, such as the ocean, rivers, and rain to obtain drinkable water.
- Reuse and Recycle refers to repurposing the wastewater following disinfecting of disease-causing pathogens.
- Protection refers to preventing further contamination of natural water resources by restricting the discharging of wastewater into clean water resources

# Conclusion

I found the research on water treatment, its impact on the environment and its importance very fascinating. I hence decided to take this literature research based project with Ecolab into another connected set of projects – one was with Safe Water Network to help understand and amplify the impact created by water ATMs, and the other was with YSDGL (Young Sustainable Development Goals Leadership). Please see Report “Clean Sustainable Water for All” for next steps on this very crucial initiative.

# Bibliography

CDC. (n.d.). Retrieved from https://www.cdc.gov/healthywater/drinking/public/water_treatment.html

SDG. (n.d.). Retrieved from https://sdg-tracker.org/water-and-sanitation

UN. (n.d.). Retrieved from https://www.un.org/sustainabledevelopment/water-and-sanitation/#:~:text=In%202020%2C%2074%20per%20cent,level%20of%20service%2C%20in%202020.

WebMD. (2022, April 04). Retrieved from 6 Reasons to Drink Water: https://www.webmd.com/diet/features/6-reasons-to-drink-water

Coolpex. (2021, March 14). 5 Reasons Why You Should Drink Pure and Fresh Water Daily. Retrieved from https://www.coolpexarabia.com/blog/5-reasons-why-you-should-drink-pure-and-fresh-water-daily/

WHO. (2022, March 21). Drinking Water. Retrieved from https://www.who.int/news-room/fact-sheets/detail/drinking-water#:~:text=Water%20and%20health,individuals%20to%20preventable%20health%20risks.

Ecologix. (n.d.). Retrieved from Water Purification: https://www.ecologixsystems.com/library-water-purification/#:~:text=Water%20purification%20is%20the%20process,fit%20for%20a%20specific%20purpose.

CGWB. (2012, May). Drinking Water Specification. Retrieved from http://cgwb.gov.in/documents/wq-standards.pdf

FAO. (n.d.). WATER QUALITY MONITORING, STANDARDS AND TREATMENT. Retrieved from https://www.fao.org/3/x5624e/x5624e05.htm#:~:text=Drinking%20water%20should%20have%20a,organic%20matter%20under%20aerobic%20conditions

Apure. (2022, 07 19). Retrieved from 3 Main Water Quality Parameters Types: https://apureinstrument.com/blogs/3-main-water-quality-parameters-types/

Sensorex. (n.d.). Types of Water Quality Parameters Explained. Retrieved from https://sensorex.com/2021/09/20/three-main-types-of-water-quality-parameters-explained/#:~:text=Some%20of%20the%20aspects%20of,depend%20on%20the%20water's%20temperature.

Tech, A. (2019, August 19). Retrieved from https://www.aquatechtrade.com/news/water-treatment/sustainable-water-essential-guide

WHO. (n.d.). Retrieved from https://www.who.int/europe/about-us/our-work/sustainable-development-goals

Tracker, S. (n.d.). Retrieved from Ensure access to water and sanitation for all: https://sdg-tracker.org/water-and-sanitation

UN. (n.d.). Retrieved from Water and Sanitation: https://sdgs.un.org/topics/water-and-sanitation

UN. (n.d.). Retrieved from Goal 6: Ensure access to water and sanitation for all: https://www.un.org/sustainabledevelopment/water-and-sanitation/#:~:text=In%202020%2C%2074%20per%20cent,level%20of%20service%2C%20in%202020.

Kemira. (n.d.). Retrieved from Kemira Oyj : Exploring sustainable water treatment solutions: https://www.marketscreener.com/quote/stock/KEMIRA-OYJ-1412476/news/Kemira-Oyj-Exploring-sustainable-water-treatment-solutions-32395723/

JJM. (n.d.). Retrieved from Jal Jeevan Mission: https://jaljeevanmission.gov.in/

Jalshakti, M. o. (n.d.). Retrieved from About JJM: https://jaljeevanmission.gov.in/about_jjm

Jalshakti, M. o. (n.d.). Retrieved from Village wise percentage FHTC coverage: https://ejalshakti.gov.in/JJM/JJMReports/Physical/JJMRep_VillageWiseFHTCCoverage.aspx

PIB. (n.d.). Retrieved from YEAR END REVIEW 2022: DEPARTMENT OF DRINKING WATER AND SANITATION, MINISTRY OF JAL SHAKTI: https://pib.gov.in/PressReleasePage.aspx?PRID=1886953

SWN. (n.d.). Retrieved from https://safewaternetwork.org/our-work/india/

Network, S. W. (n.d.). Retrieved from Safe Water Network: https://safewaternetwork.org/our-work/india/

PennState. (2022). Retrieved from The Water We Drink: https://extension.psu.edu/the-water-we-drink

McGill. (n.d.). Retrieved from Water is Life: https://www.mcgill.ca/waterislife/

UN. (n.d.). Retrieved from International decade for action: https://www.un.org/waterforlifedecade/water_and_sustainable_development.shtml

KentRO. (n.d.). Retrieved from Health Benefits of Drinking Pure Water: https://www.kent.co.in/blog/health-benefits-of-drinking-pure-water/

Water, A. (n.d.). Retrieved from Different Water Filtration Methods : https://www.freedrinkingwater.com/water-education/quality-water-filtration-method.htm

CPCB. (n.d.). Retrieved from Central Pollution Control Board: https://cpcb.nic.in/water-quality-criteria/

To The Point. (2018, Nov 21). Retrieved from Dhristi IAS: https://www.drishtiias.com/to-the-points/paper3/to-the-point-paper-3-water-atms