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Principles and Development of Drinking Water Purification Technology

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Abstract. The presented paper studies the purification process of water used for drinking, its ways and principles, and its historical evolution. Impure water can be a cause of many dangerous diseases that can take lives. According to the WHO report, 1.4 million people die every year due to polluted water. This paper explores the historical background of water purification, its recent methods, and its aftereffects. In the past, it started from ancient Egypt's alum (saltish mineral) and Greek cloth filters to Snow's cholera link and the use of chlorine to make the dirty water drinkable. Then modern technology came, which includes processes like reverse osmosis, advanced oxidation, and nanofiltration, along with the study of cases such as Singapore's NEWater recycles, New York's UV. Clean water development can be successful with dedication, awareness, and access for everyone around the globe is possible.

Keywords: Water Purification; Reverse Osmosis; Advanced Oxidation; Nanofiltration; Global Access.

1. Introduction

1.1. Why is Drinking Water Purified?

Every living being on the earth needs water to survive, but humans need safe and clean water for drinking purposes. Taking water from a random water source (lake, river or sea) is not clean enough to use it directly for drinking, it needs purification treatment. If we take any water randomly from our environment, it will contain many microbes, germs, sand, dirt, and many more insects that are harmful to health. They can be the cause of many viral and bacterial diseases like typhoid, cholera, and diarrhea. These diseases can endanger many lives, especially children and old people, if not treated on time. Ancient people experienced many tough days fighting these diseases and learned from their experience that water is responsible for carrying these diseases from one place to another. After the emergence of science, it was made clear that the real culprits were the germs present in water, called pathogens. As per the current report, 1.2 billion, that is one in every four people, can be victims of diseases because of no access to clean water. Dirty water takes about 1.4 million people's lives due to spreading diseases like diarrhea and cholera. Children under the age of five years get sick easily in areas of Africa and Asia, where 300,000 die every year from water-related diseases. It is disappointing to know all these sad realities, which is why drinking water needs to be clean and safe. Purified water can stop this damage by stopping the transfer of germs from place to place. Clean water is also lightweight, pleasant to taste, and easy to digest, which keeps a person safe and healthy. If the water is not purified properly, then humanity can face many serious health problems at different times, as in ancient times. The World Health Organization's data has shown that purifying water can save 30% of global children's lives caused by diarrhea. [1] Females in remote areas are often seen to bring water from faraway water sources, wasting their time and energy just to get the water, which is mostly dirty and unsafe. Everyone in this world deserves to be healthy, safe, and happy, which is the direct effect of purifying drinking water.

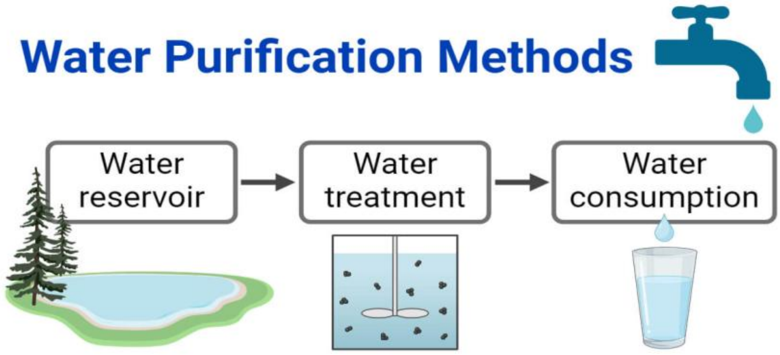

Figure 1. Watwe Purification Methods

The above figure 1 shows how water is treated from a dirty source to a clean stage for drinking.

1.2. How is it Purified Now?

Humanity had to do something to avoid these dangers to health and safety, so it combined ancient and modern methods to provide a solution for cleaning drinking water. In this way, water is purified properly step by step process. For this process, raw water taken from a river or any natural source is passed through the first step, known as coagulation, which is a process of sticking dirt particles together with the help of chemicals like alum, making large clumps of dirt that can be removed easily from the water. After that, sedimentation is done, which makes these large clumps come down to the bottom of the utensil and is removed directly. Next is filtration which uses layers of sand, gravel, or other filter media to remove remaining contaminants (e.g., bacteria or sand). Water is pumped through these layers to remove the remaining contaminants from the water. The final process is disinfection; this uses either chlorine, ozone, or ultraviolet light to kill any remaining microorganisms present in drinking water after it has passed through the filtration processes. For big cities with salty water, another process is used, known as reverse osmosis, which passes water through thin membranes by exerting pressure to stop the minerals, salts, and harmful microorganisms. In 2026, for instance, automatic systems are installed with sensors to monitor the water quality all the time, which can adjust it by default. In underdeveloped countries, factual data shows that only around 38% of people have clean water, and the rest of the world's population has about 73% safe water[2]. Easy ways, such as boiling or ceramic filters, are used there due to the absence of any filtration plant nearby. These steps are crucial for cleaning water from any kind of dirt or germs. The table 1 below shows common filtration methods.

Table 1. Filtration Methods

Method	What it Removes	How it Works
Coagulation	Tiny dirt, particles	Chemicals make them clump
Sedimentation	Heavy clumps	They sink and get removed
Filtration	Bacteria, sand	Water goes through layers
Disinfection	Germs, viruses	Chlorine or UV kills them
Reverse Osmosis	Salts, chemicals	Pressure through membrane

This method makes sure that the tap water is clean and ready to drink. Figure 2 shows that of the sedimentation process shows the steps from coagulation to clean water.

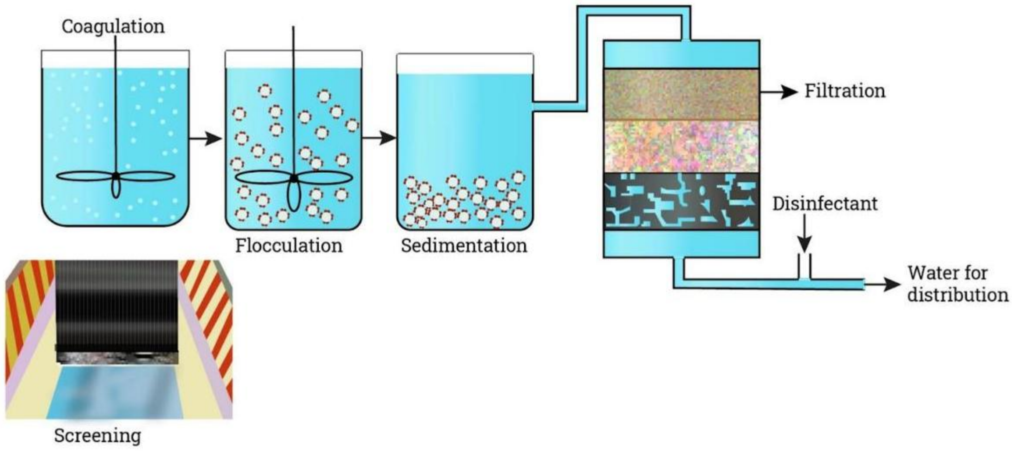

Figure 2. Sedimentation Process

1.3. What is it Doing?

Drinking water purification is vital for human beings as it works like a lifesaver. As per the UN report, about 1.4 million lives can be saved every year by cleaning drinking water. Since the 1990s, in Europe, about 50% of pollution has been treated and purified in river water, also resulting in saving marine life. Used water can be recycled again to avoid the scarcity of water in some places. It is also economically friendly as it can save money and resources by saving precious lives. According to the World Health Organization, $260 billion is spent on increased workload due to the diseases caused by dirty water and medical bills every year. In contrast, countries can develop better because clean and good water can help factories and industries to become more successful. However, we still have fights over purified water in continents like Africa and Asia, because 2.1 billion people don't have access to clean water. Current challenges of microplastics or forever chemicals (PFAS) are also growing faster. Overall, it is building a healthier planet by filtering water [2]. The below figure 3 shows the whole water purification process step by step.

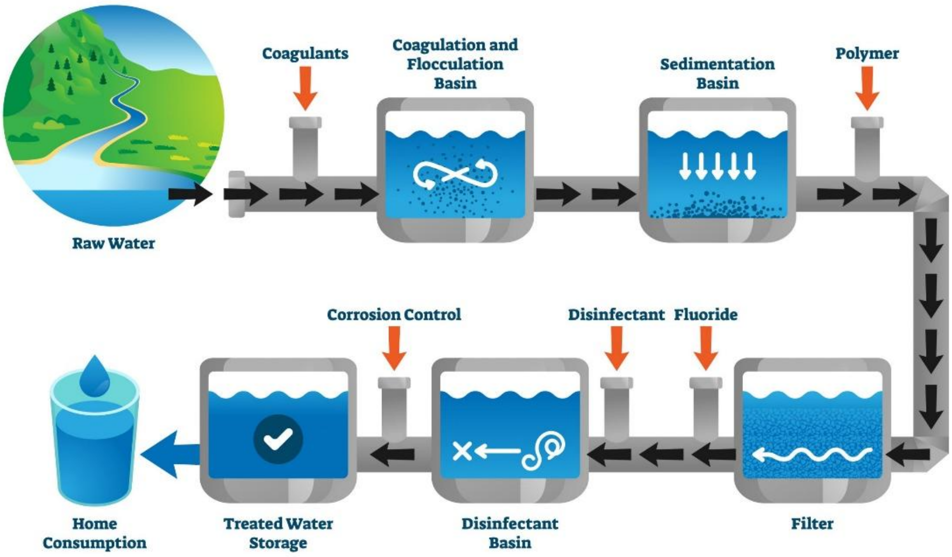

Figure 3. Water Purification Plant

The Historical Background of Drinking Water Purification

For centuries, the purification of drinking water has been a challenge for humanity. People have always suffered a lot to purify water for drinking and to save many lives, especially the lives of little ones, from germs and diseases caused by unclean water. We will explore how it began in history, how it continued till now, and how the methods have changed with the passage of time.

Indian and Greek written scripts have talked about water cleaning systems for many centuries, around 4000 BC [2]. For instance, according to Sanskrit texts from India, water can be cleaned by sunlight, boiling it up to the highest temperature, or by the filtration method using sand or charcoal to kill germs and bad smells. Greeks also proposed a solution to clean dirty water by straining it through different membranes to remove tiny particles. Egyptian people around 1500 BC used their own method, known as coagulation, to purify drinking water, in which they used a chemical named alum to attract all dirt particles and stick them together to make large lumps of dirt which could be removed easily. This method is still used in cleaning water and is very useful for the purification process.

A new kind of simple filter was constructed in 500 BC by a Greek doctor whose name was Hippocrates. He used to call it “Hippocratic sleeve”. He used a single cloth as a bag to filter boiling water and separate small dirt particles. He said that all dangerous diseases are caused by the bad smell of the water, so we should remove the bad smell first. Therefore, his method was useful in cleaning the smell of water. Around 312 BC, the Romans made huge water containers to collect clean water from other places. There were huge and long-distance bridges made of stone that were used to carry water to big cities. They stopped using water from dirty rivers and used proper membranes to filter out the dirt. In the 1700s in Europe, more experiments were started by scientists to completely purify the drinking water. Furthermore, in 1746, France presented the first patent for a filter made of wool, sponges, and charcoal. These materials caught dirt in a very convenient way.

The first water treatment plant for whole city was opened in 1804 in Paisley, Scotland, which worked on slow sand filtration, where water passed from layers of sand to become clean and tasty. James Simpson, an engineer from England, discovered slower sand filters in England in 1827, which soon reached London. These filters usually remove the dirty color and smell of the water to ensure the removal of germs from it.

The tiny particles that cause diseases, called germs, were first discovered in the 1800s. John Snow, a physician in London, claimed in 1854 that contaminated water was the source of cholera. People received water from a pump on Broad Street, and many became ill as a result. Snow studied the cases and concluded that the sewage line had contaminated the pump. He took the pump handle off, and the illness was reduced. It showed that water was the main vehicle for spreading diseases. Another scientist, Louis Pasteur, proposed a theory known as germ theory. According to him, diseases were caused by small microbes. This motivated people to invent better cleaning methods. In the late 1880s, in the US at places like the Massachusetts State Board of Health, sand filters were tested. As per their inquiry, these filters can remove about 99% of bacteria.

Early 1900s was the era when disinfection methods became popular. Jersey City, New Jersey, had begun to use chlorine element to kill germs in water. It was considered a huge breakout in history because before this method, diseases like typhoid finished around thousands of lives. Death rates caused by Typhoid fell by 90% in coming years. Europe solve this problem in 1900s by using ozone gas to kill the microbes in water with no effect on its taste. In 1914, the US Public Health Service established a set of rules for drinking water cleaning process, it mainly concerns about bacteria’s presence in the water. At first, only trains and ships were under these rules, but with the passage of time other states also adopted them.

After World War II, in the middle of 1900s, industries and factories produce more poisonous chemicals which polluted the drinking water more [3]. Research from the 1960s has explored that water systems were not clean and only 60% were up to the standards of purification process. It pushed the US to present a Safe Drinking Water Act in 1974, which set rules for all public water in the country to protect people against over 90 contaminants. From the above information, we came to know how much humanity has suffered from getting fresh and clean water for drinking.

2. Current New Drinking Water Purification Technology and Principle, Proved by Cases

Cleaning water for drinking has become more modern and faster with technological advancements. In recent years, humanity is facing more serious pollutants like tiny plastics, chemicals called PFAS, and it has become hard to find fresh water in some places. To solve this serious problem, scientists and researchers try to come up with modern methods. By 2026, many new technological methods will be in use for cleaning water. One of them is reverse osmosis (RO), whose working principle is to push water through a small hole that blocks contamination. Just like gravity always works from top to bottom, from high to low, similarly, water also flows from clean to unclean to mix things up, but in the RO process, this natural phenomenon is being reversed by pushing unclean water through such a membrane [4] that can pass clean water and leave unclean particles outside the membrane. It can clean up to 99% chemicals, bacteria, viruses, and minerals. Energy is used in this process, and it also requires a lot of water. Anyhow, all this explains that RO can recycle unclean water to make it drinkable. According to data, around 99.9% of PFAS is reduced by this process [5]. Below figure 4 demonstrates the RO process through the membrane.

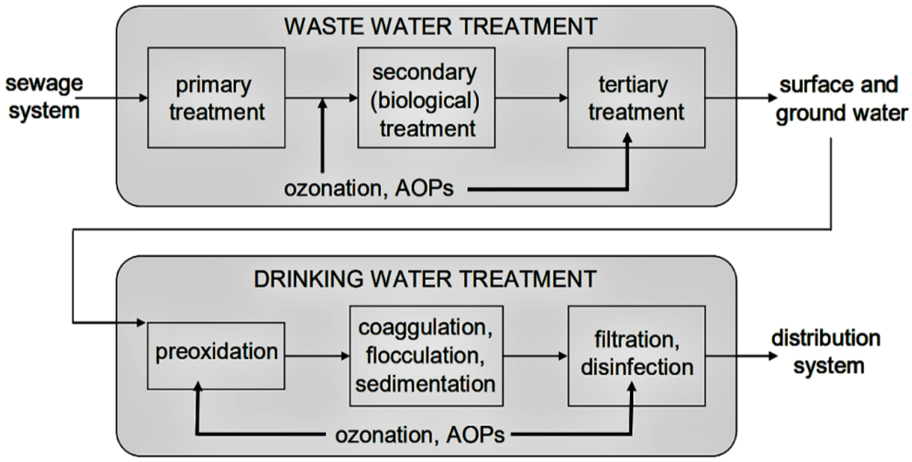

Figure 4. RO process through the membrane

Another method is Advanced oxidation processes (AOPs). In essence, it disintegrates hard pollutants through strong reactions. It works on creating hydroxyl radicals mixed with UV light, ozone, or hydrogen peroxide. Any germs or chemicals that slip from membrane filters cannot pass through these radicals. It works wonders for newly discovered antibiotics in water. It needs to be handled carefully due to the dangerous side at the bottom. AOPs are used in Singapore's NEWater program to recycle wastewater into pure water. In 2025, it has given 40% of clean water to the nation, and it will continue to do so in 2026 even more than before. According to a study, it helps a city without natural water sources because it eliminates 99.9% of organics and viruses [5]. Figure 5 represents the of AOPs in water treatment, where ozonation and AOPs fit in the steps.

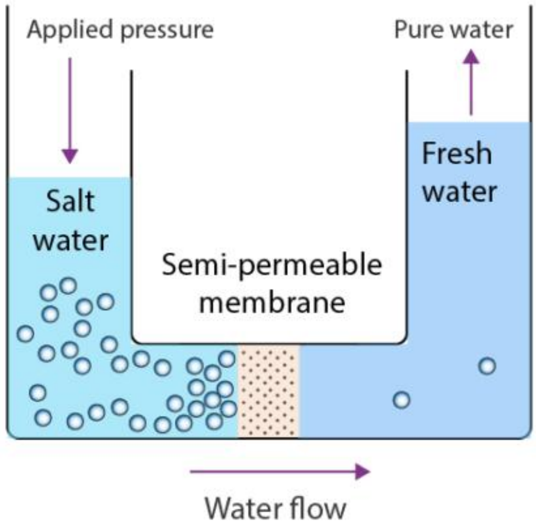

Figure 5. AOP in Water Treatment

Next method is Nanofiltration method, it is like RO with a slight difference, it blocks bad minerals from passing through while lets some good minerals pass through its membranes. Size-based filtering principle is used with nano-sized holes in the membrane, using less pressure than RO. This keeps water's taste natural and less energy is consumed. In the Netherlands, Vitens company uses it for surface water, treating 100 million liters a day. It saves energy use by 30% compared to RO, and data from 2020 (still relevant in 2026) shows better taste and less waste.

UV disinfection method is also a method of cleaning water, which uses ultraviolet light to kill germs' DNA so they can't be able to reproduce and spread a disease. Chemicals are not used, which results in a pleasant taste. It is a relatively fast way of cleaning water. In this process, a light at 253.7 nm wavelength hits the microbe genes and destroys its structure. It is highly effective at eliminating bacteria that chlorine overlooks, like cryptosporidium. Since 2013, their massive UV plant in New York City has been processing two billion gallons every day. By 2026, it will be even more effective thanks to smart sensors. In large cities, it mitigates epidemics by 90%, according to statistics [5].

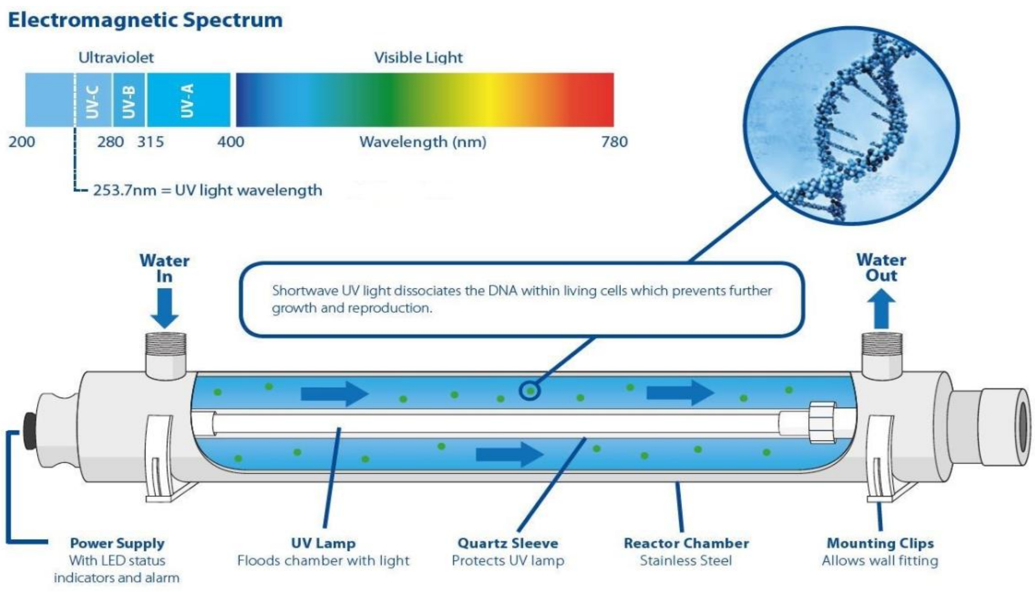

Figure 6. UV system diagram

The above UV system diagram shows that the water passes the lamp, getting disinfected without extras.

Membrane bioreactors (MBRs) are the final technique. It combines membranes and biology [4]. Organic materials are consumed by insects, and the remainder is filtered through a membrane. It combines ultra-fine filters for a deep clean output with activated sludge, where microbes consume waste. It is reusable and saves space. One million tons are treated every day for irrigation at an MBR facility in Beijing. Water pollution has dropped by 70% since 2010, demonstrating its benefits for crowded cities. In 2026, membranes have a longer lifespan thanks to nanotechnology [6].

To compare all these water purifying methods, here's a table of these techniques with pros, cons, and efficiency from 2026 data:

Table 2. Comparison of water purifying methods

Technology	Principle	Removal Efficiency	Pros	Cons	Case Example
Reverse Osmosis	Pressure reverses natural flow through the membrane	99% salt, germs, PFAS	Very thorough, adds hydrogen for health	Wastes water (30-50%), high energy	Orange County, USA – 100M gallons/day recycled
AOPs	Radicals break down pollutants	99.9% organics, viruses	Handling new contaminants	Costly, needs expertise	Singapore NEWater – 40% national supply
Nanofiltration	Nano-pores filter selectively	90-95% hardness, salts	Energy-saving, keeps minerals	Less effective on tiny molecules	Vitens, Netherlands – 100M liters/day, 30% less energy
UV Disinfection	Light damages DNA	99.99% microbes	No chemicals, fast	Needs clear water, no residuals	New York City – 2B gallons/day, 90% outbreak drop
MBRs	Biology + membrane filtration	95-99% organics, solids	Compact, reuse-ready	Fouling issues, maintenance	Beijing – 1M tons/day, 70% river pollution cut

3. Conclusion

The main concepts and background of drinking water cleaning technologies have been covered in this study from a variety of angles. The background was provided in the first section. It clarified the significance of cleaning water to reduce health issues caused by bacteria and dangerous microorganisms. Coagulation, sedimentation, filtration, and disinfection are the primary processes involved in cleaning and filtering drinking water. Additionally, it has demonstrated how they support financial gains, safeguard the environment, and improve health assurance. The second part discussed the historical improvements of these methods. It started with old filtering methods, such as using alum for cleaning in Egypt around 1500 BC and using fabric to filter water in Greece. It also discussed the key events, like John Snow's 1854 finding that cholera spread through dirty and germinated water and the start of chlorine used for cleaning and filtering in 1908. The next part reviewed modern techniques, such as reverse osmosis for filtering the impurities, advanced oxidation to break down hard pollutants, and cases such as Singapore's NEWater program, which reuses 40 percent of the country's water supply, and New York's ultraviolet cleaning plant that treats 2 billion gallons each day.

Access to purified drinking water is still a key need around the world because it assures good learning abilities, good health and strong communities. Ancient and modern cleaning efforts have greatly reduced illness; for example, adding Chlorine can lower the typhoid cases by 90 percent in cities during the early 1900s. Although, we still have problems regarding clean water access. According to

2025 WHO and UNICEF report, about 2.1 billion people, one in every four worldwide, did not have safe drinking water in 2024. The percentage grew from 68 percent in 2015 to 74 percent in 2024. According to these reports, at the current pace, only 81 percent of people will have the access to clean water by 2030, still leaving around 1.6 billion population without it. These percentages are higher in rural areas and poor countries, especially in sub-Saharan Africa, where only 38 percent of people in difficult settings have safe water. Climate change makes water shortages worse and requires more efforts for quick progress, up to eight times more to reach the United Nations Sustainable Development Goals [6].

In mean times, still our future is bright and hopeful because of the ongoing new developments. New methods, such as nanofiltration save energy while keeping good minerals and membrane bioreactors for cleaning waste with living microbes. Portable and solar-powered systems can also help areas without enough electricity sources. It needs more energy, strong rules, and teamwork around the world to provide safe water access to everyone. These steps could stop over 300,000 deaths each year of children under five from water-related diseases and return four dollars in health and financial benefits for every dollar spent on water cleaning.

References

[1] World Health Organization. (2025). Progress on household drinking water, sanitation and hygiene 2000–2024: Special focus on inequalities. https://www.who.int/publications/m/item/progress-on-household-drinking-water--sanitation-and-hygiene-2000-2024

[2] U.S. Environmental Protection Agency. (2000). The history of drinking water treatment. https://archive.epa.gov/water/archive/web/pdf/2001_11_15_consumer_hist.pdf

[3] Information on: https://archive.epa.gov/water/archive/web/pdf/2001_11_15_consumer_hist.pdf

[4] Centers for Disease Control and Prevention. (2012, November 26). History of drinking water treatment. https://www.cdc.gov/healthywater/drinking/history

[5] Labhasetwar, P. K., & Yadav, A. (2022). Membrane based point-of-use drinking water treatment systems. IWA Publishing. https://doi.org/10.2166/9781789062724

[6] Katu, N. (2025). Water purification technologies: Innovations and challenges. https://doi.org/10.59298/RIJEP/2025/412329

[7] Ritchie, H., Spooner, F., & Roser, M. (2024, January). Clean water. Our World in Data. https://ourworldindata.org/