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Drinking water treatment using advanced technologies

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Abstract

The presence of microplastics, bacteria, and viruses in drinking water systems is becoming a serious environmental problem. Drinking water treatments are made to improve water quality to a level where it satisfies consumption requirements. Due to the limitations of conventional methods, which need the use of chemical reagents and increase operational expenses, advanced technologies such as reverse osmosis, membrane filtration, and nanofiltration are used. These technologies are more efficient, adaptable, and have less energy consumption. The majority of bacteria and viruses can be removed by these techniques. A number of procedures known as "advanced oxidation processes" have been developed as a result of improvements in water treatment. Advance oxidation techniques show excellent potential for eliminating contaminants in both high and low concentrations. Further, advanced oxidation processes are used to simultaneously destroy resistant organic molecules and biological pollutants. But high operating cost is a major drawback of advanced oxidation processes. Disinfection is the final stage of drinking water treatment. The Solar disinfection has been found to be one of the finest methods for disinfecting drinking water, mostly because it is inexpensive and doesn't require electricity or chemicals. Disinfection of water is necessary to maintain drinking water quality across the distribution system, avoid re-contaminating drinking water within the system, and achieve a sufficient level of elimination or inactivation of pathogenic organisms present in raw water.

Keywords: drinking water treatment, conventional methods, advanced technologies, disinfection techniques.

Full length review article
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1. Introduction:

One finite natural resource is water, which is vital to human existence and essential to the environment's sustainability. It is a fundamental component of any ecosystem, both in terms of quality and quantity. However, water is not distributed throughout the world's areas equally, nor is it of the same quality everywhere. For instance, most of the major rivers of the world are badly polluted, endangering the health of living things and deteriorating ecosystems. Data from the World Health Organization show that there are 770 million people on the earth who lack access to safe drinking water, with 25 million of them utilizing surface water for their daily needs. Water treatment involves removing contaminants from a water supply for domestic and human consumption. After undergoing this treatment, the water is transparent, odorless, and safe [1-4]. Microplastics contamination of drinking water systems is becoming a serious environmental problem. Although it is yet unclear how exactly drinking water contaminated by microplastics may affect human health, when people consume microplastics through drinking water systems, it raises public health concerns. The current drinking water treatment facilities act as a barrier against the introduction of microplastics into the regular water supply from raw water. Therefore, it is crucial to understand the processes of the drinking water treatment process as well as the effects of microplastics. Worldwide, microplastics are found in freshwater environments. Human drinking water is primarily derived from freshwater [5].

Sink tanks and micro plastic pipelines can be made out of both open and closed freshwater systems. . There is evidence that freshwater all over the world contains microplastics, even in far-off places. Microplastics are found in freshwater in concentrations ranging from nearly none to several million particles in one cubic meter. Since consuming water is crucial for good health, it is presumed that microplastics in it could be harmful to people. When it comes to emerging contaminants in drinking water, microplastics should be considered. There have been recent initiatives to eliminate microplastics from drinking water using a variety of techniques and technologies, including membrane separation and coagulation [6]. One major cause of concern has been the discovery of newly discovered pollution traces in the environment. The endocrine systems of both humans and wildlife can be fatally affected by a class of pollutants known as emerging contaminants, even in minute quantities [7].

Emerging pollutants are frequently found in freshwater, hence advanced drinking water treatment techniques are required to raise the water's quality to a level suitable for human use [8]. Numerous issues with drinking water and drinking water treatment procedures are brought on by the presence of natural organic matter. These issues include (i) a detrimental effect on water quality due to problems with color, taste, and odor; (ii) higher doses of coagulants and disinfectants (which raises sludge volumes and produces hazardous disinfection byproducts); (iii) encouraged biological growth in the distribution system. The accessibility of clean drinking water is critical to human survival, and it should not represent a considerable risk to humans [9]. Traditional treatment approaches are primarily intended to remove macro characteristics including suspended particles, natural organic matter, dissolved iron and manganese etc. The type of technology required is determined by the supply of drinking water. Groundwater aeration will necessitate filtration, conditioning, and disinfection, whereas surface water coagulation/flocculation, sedimentation, various filtering processes, conditioning, and disinfection will be required. However, these systems are not very effective at removing micropollutants. There is strong evidence of new and increasing risks to the portability of water due to the development of analytical techniques as well as the increased and changing use of chemicals. Because of this, more sophisticated treatment methods are needed to guarantee the availability of clean drinking water [10].

2. Traditional treatment technologies

2.1 Coagulation and flocculation

In facilities that treat drinking water, flocculation and coagulation are used frequently. The objective is to enhance the sedimentation stage's ability to remove pollutants and suspended materials by using gravity. This process entails agglomerating, destabilizing, and neutralizing the charge of the suspended materials. In this process, physical and chemical reactions are combined. Numerous variables affect the coagulation process, such as the water's acidity, the coagulant's concentration, and the coagulant's kind. The hydrolysis of mineral salts is affected by the water pH, and how well they remove organic matter, which makes it a significant factor affecting the solubility of coagulants. The ideal pH range of 5 to 8 is when the precipitation of iron salts and amorphous aluminum hydroxide takes place [11].

To precisely determine how much coagulant needs to be added, the jar test must be performed, as a lower concentration will prevent the coagulant from serving its intended purpose of causing the grains to converge and the mass to form, while an increase in coagulant will cause the particles to disperse and the water's turbidity to rise. The researchers discovered that the rate at which turbidity, color, and natural organic materials are removed is significantly influenced by the kind and concentration of the coagulant. Coagulation and flocculation are somewhat impacted by seasonal variations in temperature. Temperature has an impact on several physical and chemical properties of coagulants, including solubility and reaction rate. Reduced temperature causes the water to become more viscous, which impairs the movement of coagulants and particles through the water [9].

2.2 Sedimentation

As a straightforward water treatment method, sedimentation process is used. Sand, silt, and clay are examples of undesirable small particulate suspended matters. These are removed from water under the force of gravity, along with some biological contaminants. The longer the water is sedimented, the more suspended solids and pathogens will sink to the bottom of the container [10].

2.3 Advantages of conventional technologies

The greater the size of a micro-plastic, the better it is eliminated during the process of coagulation and sand filtration. The type of coagulant used and the characteristics of the water (such as pH) affect the coagulation efficiency. Therefore, the higher attachment likelihood of flocs, which led to better settling, most likely drove the greater removal of larger-sized MPs during coagulation/sedimentation. Microplastics could be effectively eliminated by $FeCl_3$ and $AlCl_3$. The high cyanobacteria removal rate of coagulation and flocculation processes ensures that this algal formation is completely removed following a sand filtration system, which is one of its main advantages. Furthermore, this type of procedure permits a reduction in the production of putative disinfection by-products) precursors [11].

2.4 Disadvantages and limitations of conventional technologies

The primary drawbacks are the requirement for chemical reagents (such as aluminum or ferric salts), which raise the technology's running costs. In certain instances, significant amounts of coagulant and flocculants are necessary to attain the necessary degree of flocculation. Additionally, a certain amount of physicochemical sludge is produced; this is typically processed outside. A very easy and reasonably priced installation is a sedimentation basin. However, a sedimentation basin does require a sizable amount of space. A sedimentation basin's design is always predicated on its maximum volume [10]. The widespread use of chemicals, medications, pesticides, and solvents made the deployment of advanced technologies necessary as conventional drinking water treatment is not designed to eliminate emerging pollutants [12].

3. Advanced technologies in drinking water treatment

3.1 Reverse Osmosis

Among the most well-liked and extensively applied membrane procedures for desalination is reverse osmosis (RO), which operates under pressure. Among other membrane technologies, reverse osmosis has been utilized extensively. It is most effective at eliminating pesticides and other contaminants such as heavy metals and cyanide compounds. The RO system is able to separate dissolved solutes from water, including single charged ions such as Na^+ and Cl^-. Disinfecting the water is necessary to maintain drinking water quality across the distribution system, avoid re-contaminating drinking water within the system, and achieve a sufficient level of elimination or inactivation of pathogenic organisms present in raw water. by means of a semipermeable membrane that permits water to pass through instead of the dissolved solute [13].

The mass transfer of permeant through RO membranes can be thought of as a diffusion-controlled process known as the solution-diffusion mechanism. Permeants diffuse across the membrane substance after dissolving in it via the solution-diffusion mechanism. Due to the high hydrophilicity of the RO membrane, water can readily enter and exit the membrane polymer structure. Because of RO, nearly 97% of all organic and inorganic organisms are eliminated from the surface and groundwater [14]. RO can virtually eradicate all bacteria, viruses, and protozoa and simultaneously remove multiple ions and metals. As for the drawbacks, it must be emphasized that RO needs pre- and post-treatment to shield the membrane from pore blockage and to be re-mineralized and re-hardened (to change the salinity and alkalinity content, respectively). One should consider membrane fouling as a process that can be detrimental. This phenomenon occurs because particles may accumulate on the pores or surface of the membrane, reducing its functionality. Backwashes or washing with chemical reagents are therefore necessary to avoid the pores of occlusion. Currently, RO is utilized for a range of purposes, such as quantity, the purification process, and specific separation. RO is used in the food business to pre-concentrate milk, dealcoholize alcoholic beverages, and concentrate fruit and vegetable juices [15].

3.2 Membrane Filtration and nanofiltration

Membrane technology makes possible the physical barrier used to separate the contaminants in the water. Different materials are used to make membranes, and these materials have unique properties (pore size and hydrophobicity) that restrict the kinds of pollutants that can be held in [16]. Particles, bacteria, and organic matter can be effectively removed from drinking water and wastewater via membrane filtration. Comparing membrane processes to traditional treatment techniques. It can deliver water of higher quality, reduce the need for disinfectants, be more compressed, offer easier operational control, require less maintenance, and produce less dirt. Because of their minimal pore diameters, ultrafiltration, nanofiltration, and reverse osmosis are the most effective membrane procedures for removing new contaminants [17] [18]. Complete removal of bacteria, viruses, and protozoa is possible through ultrafiltration (0.01-0.1m); color, volatile organic compounds (VOC), pesticides, sulfates, and phosphates produced by various cyanobacterial species can be removed through nanofiltration (0.001-0.01 m). The majority of bacteria and protozoa can be removed with microfiltration (0.1–10 m). For reverse osmosis (0.001 m), pre-treatment is required (flocculation, lime addition, sedimentation, fast filtration, or ultrafiltration) to lower the amount of organic matter, suspended solids, and colloidal substances. These can cause problems with membrane fouling and consequently lower operational flow and efficiency [19]. Microfiltration and ultrafiltration are the most often used techniques, even though reverse osmosis and nanofiltration effectively eliminate protozoan cysts. The efficacy of the membranes is combined with high-pressure and low-pressure membrane filtration can be employed [12]. One disadvantage of membrane processes over advanced oxidation methods is that impurities are transferred into the waste product flow instead of being removed, which means the concentrate must be treated further and disposed of [13].

4. Advance oxidation processes

Treatments such as advanced oxidation techniques work to chemically eliminate impurities by producing extremely reactive reaction products such as hydroxyl radicals. These can be produced by applying multiple oxidants at the same time, such as depending on several factors, including the water's purity, solids content, and likelihood of fouling throughout the treatment process. To mitigate this problem, systems use ozone, hydrogen peroxide, UV light, and per-acetic acid. Because advanced oxidation processes can simultaneously destroy resistant organic molecules and biological pollutants, they are an incredibly effective treatment method. Advanced oxidation techniques provide benefits over traditional disinfection methods, such as the fact that they don't produce disinfection by-products [14]. However, the high operating costs of all advanced oxidation processes are a common drawback that has restricted the widespread use of this otherwise very potent technology. However, due to the development of more effective UV lamps, visible light catalysts, and improved reactor design with the help of numerical fluid dynamics and energy simulation, both UV and solar-based photocatalysis have excellent potential for widespread application [15].

4.1 Ozone based advance oxidation processes

A strong oxidizing agent, ozone, can react with materials that are inorganic or organic. Because it produces no harmful byproducts during the process and has an elevated potential for oxidation (E° = 2.08 V), this approach has become increasingly important in the water treatment industry. The requirement to create ozone from oxygen, which demands that an electric discharge be applied over pure oxygen or an air stream, is the primary drawback. The process cannot be scaled down because of this step's high energy consumption [16].

4.1.1 Ozonation

Ozone oxidation is a complicated process that can happen directly through a reaction with dissolved ozone (O_3) or indirectly by producing radicals ($^{\bullet}OH$). Both pathways might persist during a chemical's degradation, depending on variables like the type of pollutant, the amount of ozone present, or the pH of the medium. In acidic conditions, typically direct ozonation is predominant (pH less than 4). On the other hand, the indirect method is crucial when the pH is greater than 9. Since high pH encourages the breakdown of ozone into free radicals. In ozonation processes, degradation rates frequently rise in tandem with pH. The following are other chemical processes connected to the indirect oxidation of ozone in the second reaction [25].

$$3O_3 + OH^- + H \rightarrow 2OH + 4O_2$$

$$O_3 + OH^- \rightarrow O_2 + HO_2^-$$

In the latter reaction, hydroperoxyl radicals (E° = 1.66 V) are produced quickly at the expense of •OH radicals (E° = 2.81 V), which reduces the ability to oxidize. When O_3-mediated oxidation is carried out at an acidic or nearly neutral pH, the organic molecules that make up the pollutants are directly reacted with O_3, which mostly causes the organic molecules to degrade. Ozone attack mostly targets double bonds with the formulas -C = C. O_3 production and its subsequent conversion to hydroxyl radicals are highly dependent on a variety of functional variables. Among these, the effluent's quality, temperature, pH, and the pollutant's chemical makeup and concentration all need to be taken into account [17].

The following are the key benefits of ozone: the effluent volume stays constant throughout the process, preventing the formation of sludge, installations are straightforward, and. It takes up a little area. O_3 is produced on-site, so no stock solutions of H_2O_2, iron salts, or additional chemicals are required. It can also be applied if the composition or flow rate of the effluent changes. Finally, since ozone tends to break down into oxygen, any leftover O_3 can be removed [18]. The main drawbacks are the comparatively high equipment and maintenance costs as well as the substantial energy requirements to continue the process. In waterworks, ozonation and biological activated carbon (BAC) filtration are used to get rid of bad smells and stop trihalomethanes from being produced. Ozone helps break down complex organic compounds into simpler ones that are more easily biodegradable, in addition to the BAC medium's biological oxidation and organic molecule absorption properties [19].

4.1.2 Ozone with hydrogen peroxide

Ozone can be mixed with hydrogen peroxide or ultraviolet light. One of the most often used radical processes is oxidation, which uses ozone and hydrogen peroxide (peroxide), methods for water treatment. The reaction occurs during hydrogen peroxide's breakdown: OH• radicals are created when ozone and H_2O react.

$$H_2O_2 + H_2O \rightarrow HO_2 + H_3O^+ \quad (1)$$

$$H_2O_2 + 2O_3 \rightarrow 2\ OH^{\bullet} + 2O_2 \quad (2)$$

Equation 2 is the general equation for the reaction that produces OH•. The disinfectant capacity of peroxide/ozone systems can be calculated based on the residual ozone in the effluent water, which will decrease as the peroxide-to-ozone ratio increases [29]. The main oxidation mode, sometimes referred to as hydroxyl radical oxidation or direct oxidation, is the main distinction between ozone and peroxide. Due to these compounds' reactivity, interactions with water's constituents and the efficiency of disinfection are affected differently. When carbon tubes were based on ozone residuals, peroxide was as potent as ozone or slightly more so. When ozone and hydrogen peroxide are employed together, the primary causes of pathogen inactivation are mechanisms involving the oxidation of pathogens via direct ozone reaction and hydroxyl radicals [20]. When ozone and UV radiation are combined, a photochemical interaction occurs between them which take place in both the gaseous phase and the aqueous solutions causing radical reactions. Because of their low selectivity potential and high redox, radicals can initiate more productive processes than just ozone. In the aqueous phase, the ozone photolysis reaction is in equation 3. Radicals are created as a result of secondary processes that absorb hydrogen peroxide, as in equation 4. Radicals are created from hydrogen peroxide photosynthesis as in equation 5 [21].

$$\text{Ozone + water + sunlight} \rightarrow O_2 + H_2O_2 \quad (3)$$

$$2O_3 + H_2O_2 \rightarrow 2OH^{\cdot} \quad (4)$$

$$2H_2O_2 + hv \rightarrow 2OH^{\cdot} \quad (5)$$

The O_3/UV combination quickly produces high quantities of hydroxyl radicals, making this method suitable for these kinds of processes involved in mineralization. As a result, one of the most popular advanced oxidation processes for the degradation of organic molecules in general, including acids, alcohols, and low molecular weight organochlorines (trihalomethanes, trihalomethanes, etc.), is ozonation in the presence of UV radiation. The fact that the synthesis of bromate is restricted when O_3 and UV are used together is another significant benefit. O_3 and UV work together to speed up the degradation of azo dye at all pH levels [22].

4.2 Photocatalysis

By absorbing photons with energy above a semiconductor's bandgap, photocatalysis is the process of speeding a photochemical reaction in the presence of the semiconductor. When contaminants are present in a fluid phase while the catalyst is in a solid phase, this is known as heterogeneity. In the water and wastewater treatment industries, photocatalysis is a cutting-edge oxidation method that is specifically employed for the oxidative elimination of Micropollutants and microbiological pathogens. Heterogeneous photocatalysis can remove the majority of organic contaminants [23].

TiO_2 is a widely used photocatalyst due to its readily available nature, low toxicity, affordability, and well-established physical characteristics. When TiO_2 is exposed to ultraviolet light at the correct wavelength, which is in the range of 200–400 nm, electrons will be photoexcited and migrate into the conduction band. Photonic stimulation produces pairs of electrons and holes which sets off a complicated series of oxidation and reductive reactions. Therefore, in a pretreatment phase, the biodegradability of compounds that decompose rapidly can be improved. In general, polishing procedures like tertiary clarifying steps in municipal wastewater treatment plants can be used to photocatalytically eliminate persistent substances like antibiotics or other micropollutants. However, because the photon efficiency is quite low and ultraviolet A radiation is only about 5% as efficient as sunshine, industrial utilization is constrained [24].

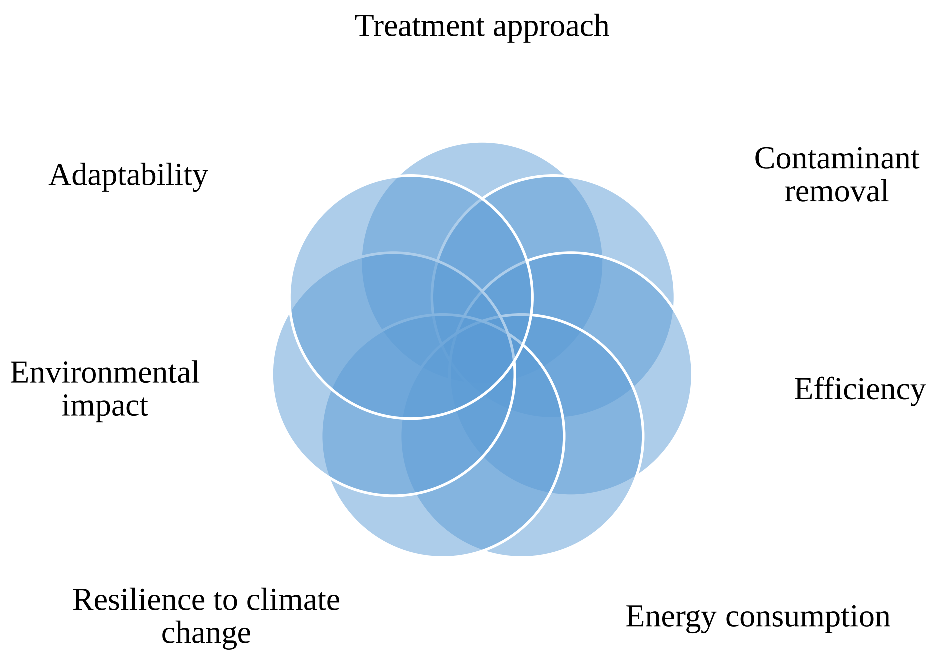


Figure 1. Advantages of advanced technologies over conventional technologies

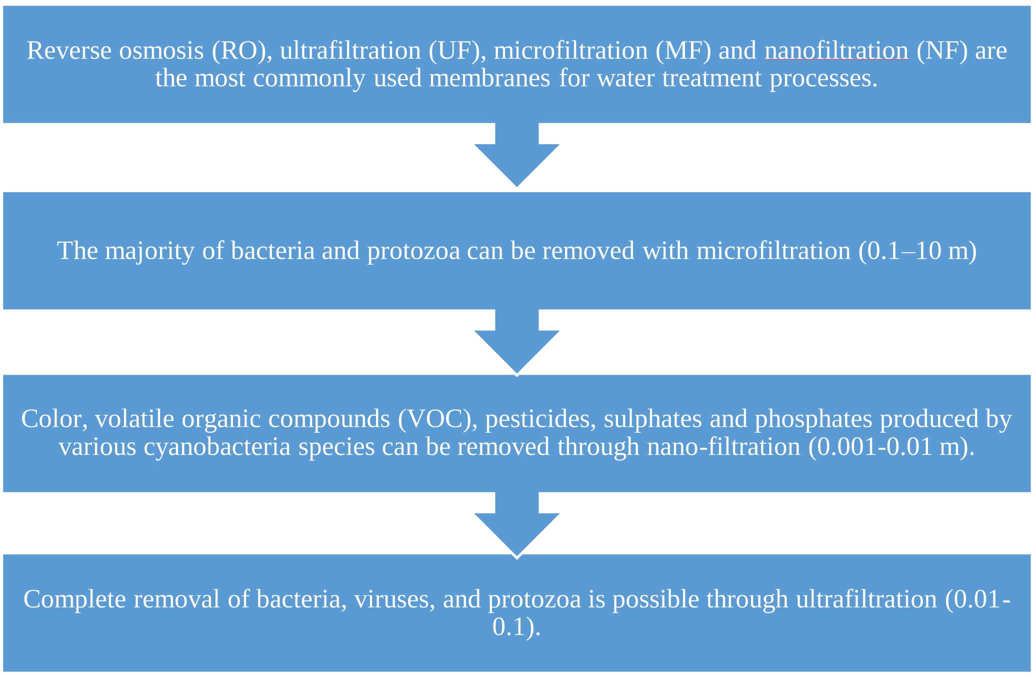
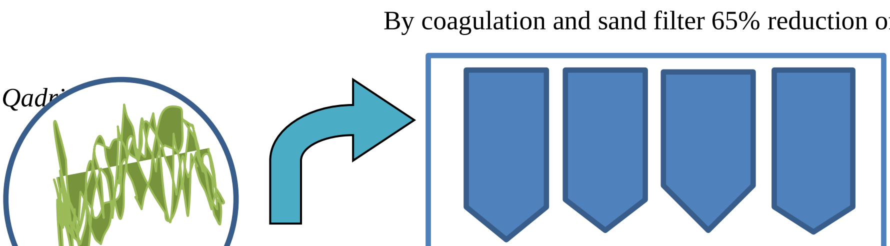


Figure 1. Membrane filtration technologies



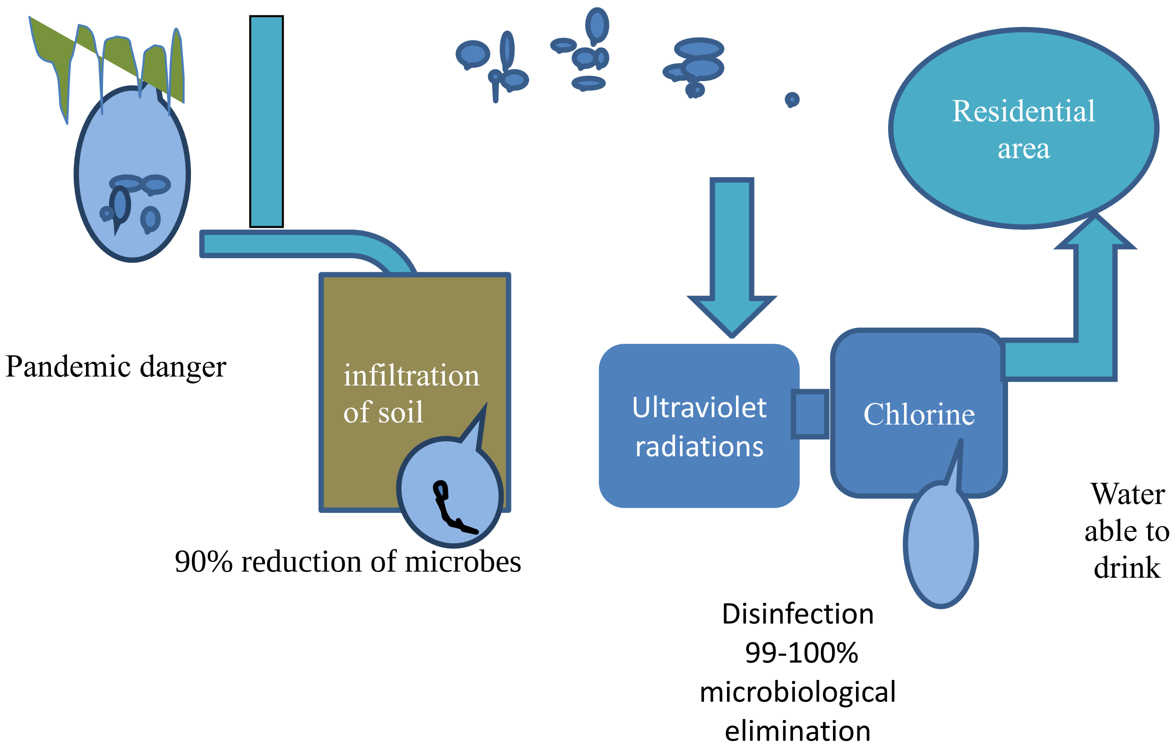


Figure 3. Removal of microbes by different technologies

Table 1. Water treatment technologies and their advantages and disadvantages

Method	Advantages	Disadvantages
Reverse Osmosis	Salt removal efficiency of 99% and simultaneously remove large number of metals.	Regular maintenance and filter changes are necessary. Reverse osmosis system installation is expensive. The entire process moves very slowly.
Membrane filtration	precise filtration with varying pore diameters	lower flow rate and simple clogging
Slow sand filtration	Most popular, offered in a range of substrate kinds and least expensive	May not be enough to completely remove infections on its own.
Ozonation	No dangerous byproducts produce and also not harmful to people.	The primary drawback is the need to create ozone from oxygen, which necessitates passing an electric discharge over either an air stream. The process cannot be scaled because of how much energy this step consumes.
Hydrogen peroxide	less dangerous and weaker oxidizer than chlorine	It is costly and require large dosages in order to work
Photocatalysis	TiO_2 and ZnO are two types of photo catalysts that have many benefits, including their chemical and physical stability, affordability, and environmental friendliness.	Novel photocatalyst preparation is a labor-intensive process that usually requires large financial investments.

A unique photocatalyst called KRONOClean 700 has its bandgap adjusted to lower energy so that it can absorb more solar light. When exposed to visible light, compounds including TiO_2 and tungsten trioxide, as well as some fullerene derivatives like fuller and C60 enclosed in poly (N-vinylpyrrolidone), exhibit a photocatalytic action. They do, however, produce O_2, which is rarely expensive and has less oxidation potential than TiO_2. TiO_2 nanoparticle performance can also be improved by making nanotubes that are 25%–40% more effective and by doping noble metals to lessen e/h+

recombination. It has been demonstrated that TiO_2 photocatalysis kills microorganisms when drinking water is treated with it [25]. The lack of a residual disinfectant to sustain disinfection in a municipal distribution system is a disadvantage of employing TiO_2 photocatalysis as a drinking water disinfectant. To maintain a residual disinfection in the distribution system, the drinking water treatment plants will likely need to apply a secondary disinfectant, such as chlorine, in addition to TiO_2/UV treatment. This is because TiO_2 photocatalysis in water produces hydroxyl radicals, which have a short half-life and are very reactive. TiO_2 also exhibits excellent resistance to alkalis and acids [26].

The ability of semiconductors to produce charge carriers in response to light irradiation, followed by the production of free radicals like OH^-, which triggers further processes that ultimately lead to the creation of CO_2 and H_2O, best describes the mechanism of heterogeneous photocatalysis. Therefore, the following characteristics of heterogeneous photocatalysis are most appealing: the contaminants break down into CO_2 and other inorganic materials, and the procedure is executed in normal surroundings. All that is required for the reaction to begin is the presence of oxygen and ultra bandgap energy, both of which are readily obtained from the sun and air [27]. By converting harmful high-valence heavy metal ions into low- or zero-valence metals, photocatalysis can be utilized to eliminate heavy metal ions from water. Oxygen anions (like CrO_4, Cr_2O_7, or $HCrO_4$) and cations (like Cr^{3+}) release chromium ions and related compounds into the environment, which are carcinogens that directly impact human skin and internal organs. Chromium in water has been treated through the use of photocatalysis. TiO_2-ZrO_2 has proven to be effective in removing heavy metal ions because of its good sorption characteristics and relatively high chemical stability [28].

5. Disinfection technologies

Usually the last step in the drinking water treatment process, disinfection aims to eliminate the pathogenic microorganisms that cause illnesses when contaminated water is consumed. These consist of: its effectiveness against helminthes, viruses, bacteria, and protozoa as aquatic pathogens; the degree of precision with which the procedure can be observed and managed; its capacity to generate a residue that offers an additional line of defense against potential post treatment contamination brought on by distribution system flaws; the treated water's aesthetic quality; and the technological capacity to do the procedure on the scale necessary for public water supplies. Disinfection is possible for two reasons: to eliminate pathogens from the raw water supply and to reduce the risk of recontamination during distribution and storage [29].

5.1 Ultraviolet Disinfection

Ultraviolet disinfection is a physical disinfection process. Within the electromagnetic spectrum, ultraviolet light (UV) has wavelengths ranging from 100 to 400 nm. UV disinfection is gaining popularity in industrial settings due to its efficacious ability to destroy bacteria in water. Protozoa, viruses, and bacteria can all be diminished or rendered inactive by ultraviolet radiation without changing the chemical makeup of water. UV light disinfection of water has been practiced since 1906. Drawing from the results of past research employing ultraviolet radiation as a water purifier, UV therapy is very efficient and successful in killing bacteria [40]. Mercury, LED and portable ultraviolet lights are the types of lamps that have been used in earlier studies. Regarding the process of disinfecting water with UV light, it involves irradiation, stirring, flowing, dipping, and stirring. Different semiconductor materials can be used to create UV-LEDs at different wavelengths. Prior studies have employed UV radiation of the following wavelengths to disinfect water: 254 nm, 264 nm, 269 nm, 272 nm, 275 nm, 282 nm, and 366 nm. The most often utilized wavelength is 254 nm. It has been found that the following UV exposure times are effective for disinfecting water: 75, 90, 48, 4 -5 minutes, 25 minutes, and 110 minutes [41]. Microorganisms of interest: UV radiation used by earlier researchers killed bacteria, spores, Coliform, Staphylococcus aureus and B. cereus bacteria found in water. Since ultraviolet (UV) radiation can effectively destroy a wide range of microorganisms in water, it is being used to disinfect water more frequently. UV radiation has many advantages over conventional chemical disinfection techniques such as ozonation or chlorination, such as no need for chemical additions, no production of toxic disinfection byproducts, and no development of bacterial resistance to disinfectants. An alternative to chemical additions for treating surface water is UV disinfection. There are more than 7000 municipal UV disinfection plants worldwide, and small home UV disinfection systems are also available [30].

The following are the benefits and drawbacks of using UV light for water treatment. The benefits of UV include that most viruses, spores, and cysts are effectively inhibited by UV light. UV disinfection is a physical-chemical disinfectant process that eliminates the need for the creation, removal, transportation, or storage of hazardous chemicals. Aquatic life or humans are not harmed by the residues. UV disinfection is simple to operate for the person operating it. It requires less contact time than other disinfectants; with low-pressure lamps, takes about 25 to 30 seconds and equipment for UV disinfection requires less room than other methods [31]. The drawbacks of UV are certain viruses, spores, and cysts may not respond well to low dosages, There are instances when organisms can reverse and repair the negative effects of UV radiation through "repair," also referred to as "dark repair" in the absence of light or "photo reactivation."**,** tube fouling must be controlled through preventative maintenance programs, UV disinfection may not be effective in wastewater due to turbidity and total suspended solids. TSS concentrations greater than 30 mg/L do not appear to be effective for low-pressure UV disinfection, UV disinfection is more expensive than chlorination [32].

5.2 Chlorine dioxide disinfection

Chlorine dioxide can eliminate harmful microorganisms from fruits and vegetables, including bacteria, fungi, and viruses, while also disinfecting drinking water without compromising its flavor. Chlorine dioxide has been added to and occasionally substituted for other methods of treating drinking water in the United States for over 50 years. Chlorine dioxide is advised as a disinfectant because it eliminates microorganisms even at low concentrations. Water can be treated with chlorine dioxide for a variety of purposes, including lowering the amount of dangerous organisms in the water or raising its quality by getting rid of impurities [45]. Strong enough to quickly inactivate bacteria, viruses, and parasites like Giardia, chlorine dioxide is a disinfectant. Because it does not react with common raw water constituents to produce problematic, strictly regulated compounds like trihalomethanes (THM) and haloacetic acids (HAA), which are byproducts of chlorination, chlorine dioxide has become more and more popular in the drinking water industry in recent years. It is an essential tool for meeting standards for drinking water quality and adhering to the ever- stricter legal requirements regarding the amounts of treatment byproducts [46]. Chlorine dioxide is more soluble than chlorine and has a 2.63 times greater capacity for oxidation than chlorine gas. The most recent study examined how well- mixed salads treated with chlorine dioxide as a sanitizer reduced the amount of human norovirus. The efficacy of a chlorine dioxide solution prepared by dissolving 2000 mg/L of chlorine gas in water was examined. When this solution of chlorine dioxide was tested against different strains of bacteria, it was found to be effective at concentrations between 5 and 20 mg/L, which resulted in a 98.2% reduction in bacterial activity. It also showed antiviral effects against strains of H1NI and EV71 at 46.39 mg/L and 84.65 mg/L, respectively. It was discovered that the prepared chlorine dioxide solution was safe when tested in rabbits at a concentration of 50 mg/L. Furthermore, 40 mg/L of drinking water did not exhibit any toxic symptoms when tested for subchronic oral toxicity [47].

The effectiveness of chlorine dioxide gas in the capacity of disinfectant was covered in three publications from 2013. The results showed that the one-time disinfection procedure decreased the bacterial and fungal loads by 65% and 30%, respectively. Twice-daily disinfectant spraying decreased the load of bacteria by 74% and the load of fungi by 38%. It found that within ten minutes of application, applying 0.02% chlorine dioxide to dental instruments completely disinfected the instrument. The contaminated instruments were cleansed of HCV by the chlorine dioxide solution at a concentration of 0.02%. Consequently, the authors suggest that ultrasonic disinfectants and chlorine dioxide are good substitutes for potentially harmful disinfectants. Furthermore, researchers found that chlorine dioxide worked better than just chlorine [48].

5.3 Solar disinfectant and water treatment

In many African and Asian nations, solar water disinfection is a well-known method of disinfecting water that is inexpensive and easy to use for removing harmful microorganisms from drinking water. It has also been shown that SODIS can inactivate or degrade a variety of chemical contaminants in water and increase the antimicrobial effectiveness of chlorine. Furthermore, SODIS is an approachable technique because it employs solar heat and light energy to inactivate waterborne pathogens without the need for chemical disinfectants [33].

Mechanism of solar disinfection

According to recent research, two primary factors—increasing temperature as a result of exposure to light and ultraviolet radiation (A and B) from the sun are responsible for the sterilization in the solar disinfection process. The majority of ultraviolet C is absorbed as the light travels through atmosphere, and UVB has an antibiotic effect that is 100–1000 times stronger than UVA. It has been discovered that UVB can travel through the atmosphere and into naturally occurring through the part of the surface of earth covered with water, where it can induce mutations, potentially apoptosis, and imminent cell death, all of which have a significant disinfecting effect [34]. Numerous investigations have verified the impact of elevated temperatures due to the effects of sun radiation on different types of water microorganisms, especially when combined with UV radiation. The method involves putting purified water in clear plastic bottles (usually 1-2 liter polyethylene terephthalate bottles) and exposing them to direct light of the sun for at least five to six hours on a bright day before deciding it's drinkable [35]. The primary advantages of solar disinfection are its independence from chemical and electrical origin, low operating and running costs (the user bears the expense of obtaining PET bottles, which need to be converted every six months), negligible alterations to the taste sensation and smell of the water, and the absence of residue generation. It is simple to use and affordably priced. After the user has PET bottles, there are no more costs, lack of dependence on power, possible effectiveness against germs, viruses, and protozoa, minor flavor and fragrance changes, lack of generation of harmful byproducts and no dependence on chemical supply [29-36]. Nevertheless, there are several disadvantages to this method, including the lengthy treatment times required for small amounts of water, the reliance on external factors (such as sunlight intensity, ambient temperature, time spent in the sun, type of microbiological contamination, water turbidity levels, and water composition and nutrients), and the peculiarities of the container (such as optical transmittance, shape, etc). Furthermore, the plastic material can be changed by sunlight into photoproducts which can leak out of the containers and into the water. This represents a major obstacle to the growing use of SODIS [37].

6. Emerging technologies

6.1 Electrocoagulation

Unlike traditional activated sludge processes and general chemical coagulation, which rely on chemicals and microbes for their tertiary treatment, electrocoagulation offers a less expensive option. The coagulation process is made straightforward and reliable by electrocoagulation, which produces coagulants electrically using metal electrodes. In electrocoagulation, an electric field causes metal electrodes to produce cations. Three steps follow one another from the production of ions to the floc formation: (1) anode production of electrons in the presence of an electric field, which precipitates out as Fe^{+3} or Al^{+3} hydroxides, or "micro-coagulants";(2) Coagulants cause the suspended particles and toxic part of colloidal in water to become unstable;(3) micro-coagulants and pollutant particle strike with one another to form micro flocs. Because no oxidant or reductant is needed, little to no environmental pollution is produced, and the sole consequence of the electrolytic reaction during the electrocoagulation process is an ion. It is known as an environmentally beneficial technique for purifying water. Electrocoagulation has been used to remove various toxic substances from drinking water. Its benefits include being environmentally friendly, easily automatable, sludge reduction, energy efficiency, and low capital expenditure.

The operational costs of this process might be high in certain places with an electricity shortage [54].

6.2. Magnetic extraction

Magnetic extraction makes use of magnetic seeds, acid, and an external magnetic field to accelerate the process of separation. Iron nanoparticles were selected for this application as magnetic seeds because of their ferromagnetic qualities, large specific surface area, and inexpensive cost. Hexadecyltrimethoxysilane was applied to the Fe nanoparticles to make them hydrophobic. As a result, microplastics in water can be magnetically extracted. Magnetic extraction works better at removing smaller microplastics. The low recovery for sediments was caused by soil particles blocking Fe nanoparticles from interacting with microplastics. Furthermore, the presence of lipophilic substances in sediment samples will significantly reduce the impact of the nonspecific binding of nanoparticles. The authors concluded that treating drinking water might be a better fit for this method [55].

7. Conclusion and future perspectives

The need to create an effective system for protecting surface and ground waters is critical due to the global shortage of water resources and the various contaminants that are dumped into natural waters by urbanization, industry and agriculture. For this purpose, treating the water before injecting them into the environment is a good financial and technological strategy. An outline of the conventional technologies and advanced technologies for drinking water treatment is presented in this work. Conventional technologies are important and useful but traditional drinking water treatment techniques have major disadvantages that keep them from being adopted internationally, including the high energy and chemical requirements. AOPs are highly successful technology for the treatment of water containing organic pollutants. Based on our investigation, we conclude that these alternatives are usually more economical, easier, and clean when it comes to photochemical technologies than traditional ones. Over the past years, there have been notable developments in heterogeneous photocatalysis (AOP), which is primarily focused on the use of semiconductor titanium oxide (TiO_2/UV). In fact, TiO_2 is extremely close to being the perfect photocalayst in several important aspects, such as being inexpensive, safe for the environment, chemically highly stable, and simple to synthesis. These factors have led to a variety of environmental and energy applications, especially in the purification of water, wherein harmful inorganic ions can be oxidized and various organic contaminants can be degraded and/or mineralized. However, the high operating costs are a common drawback. The Solar disinfection has been found to be one of the finest methods for disinfecting drinking water, mostly because it is inexpensive and doesn't require electricity or chemicals. Because of the necessity to control emerging contaminants (like protozoa), future perspectives should take the role of disinfection treatment into account. Furthermore, more research will increase our understanding of emerging contaminants and disinfection by products, leading to a greater use of alternative technologies like membrane filtration and UV-based processes. In the end, the idea of multi-step disinfection applying the disinfection process at an earlier stage rather than at the very end may present an intriguing means of enhancing the elimination of microorganisms and reducing the generation of disinfection by products.

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