

Which Disinfection Method is Effective for Water Disinfection

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Abstract

An effective drinking and pool water disinfection is the most important public health responsibility. The raw water obtained from natural sources is treated by using three basic steps: sedimentation, ventilation and filtration. With good treatment, the number of bacteria in water can be reduced by 99.5%. The water must be disinfected after pretreatment. Disinfection is generally carried out by chemical, physical or mechanical methods. The chemicals used in the disinfection process are chlorine and chlorine compounds, bromine and iodine compounds, ozone, phenol and phenolic compounds, alcohols, various dyes, soaps and synthetic detergents, ammonium compounds, hydrogen peroxide, various alkalis and acids. The use of heat and light are physical disinfection methods. With in these methods, chlorination is the most common, effective and cheapest disinfection method of water. At the same time, it is an effective microbicide against all water-borne pathogens, although it can cause by-products after disinfection of drinking or pool water disinfection. In general, other disinfection methods are used as a supplement.

Keywords: Pool; Drinking water; Disinfection

Introduction

Water is one of the most basic requirements for the individual to sustain his or her life. Global warming, pollution of resources, unplanned growth, social and political instabilities can be used and increased scars of access to potable clean water. Global warming, pollution of resources, unplanned growth, social and political instability can be used and increased access to drinking water. The concept of water deprivation has come to the fore due to all these reasons. For all these reasons, water deprivation has become a major problem in recent years [1-4]. Dissolved and undissolved inorganic salts, bacteria, parasites, viruses and organic substances in contaminated water cause many diseases. About 20% of the world's population uses unreliable drinking water, about 200 million people are infected with water-related diseases annually, and more than 2 million people die annually due to diseases (typhoid, dysentery, cholera, etc.) related to contaminated waters. For this reason, in order to protect public health, there should be no harmful microorganisms in drinking water. Potential disease-causing microorganisms that can be found in domestic wastewater are shown in Table 1 [5-11].

Potential disease-causing microorganisms in wastewater (Table 1)

For this purpose, the raw water obtained from natural sources is treated by using various physical and chemical methods in accordance with water quality standards and regulations. This process consists of three basic steps: sedimentation, ventilation and filtration. Drinking and use water is passed through the same steps and subjected to treatment. With good treatment, the number of bacteria in water can be reduced by 99.5% [12-16].

The water must be disinfected after pretreatment. There are many physical and chemical methods that can be used individually for disinfection of water. However, a small number of disinfection techniques can be used in social applications. A disinfectant needs to carry some properties in order to be used in drinking and potable water disinfection. For this reason, it is essential to offer safe water with balanced mineral distribution, not exceeding certain limit values, no disease-causing microorganisms and suitable physical qualities [17].

Drinking and using water is mainly obtained from groundwater and surface water. Groundwater is obtained from boreholes drilled from underground aquifers with a depth

of tens or hundreds of meters. These wells usually displace water in deep aquifers from the surface, and this occurs slowly over hundreds or thousands of years. Groundwater shows less pollution than surface waters. Since the organic matter on the surface takes a long time to break down by bacteria and reach groundwater, groundwater is more protected from surface pollution. The soil itself acts as a filter and allows for less pollution [18]. Surface waters consist of lakes, rivers and reservoirs. It usually has more suspended solids than ground water, and needs to be treated more safely to drink safely. Surface water is used for other purposes than drinking water and is often contaminated with sewage and industrial wastewater. As the rivers go from the beginning to the end, pollution increases because of the repeated use of water. Raw water obtained from natural water sources is purified from substances which are harmful to health by using various physical and chemical methods before being put into use. Although various methods are used to prepare water sources for drinking, the basic principles are the same [19,20].

Table 1: Potential disease-causing microorganisms in wastewater

	Microorganism	Caused Disease
Bacteria	<i>Escherichia coli</i>	Gastrointestinal and intestinal inflammation
	<i>Leptospira</i>	Leptospirosis
	<i>Salmonella typhi</i>	Tifo
	<i>Salmonella</i> (=2,100 serotypes)	Salmonellosis
	<i>Shigella</i> (4 spp.)	Shigellosis (bacillary dysentery)
	<i>Vibrio cholerae</i>	Kolera
Protozoa	<i>Balantidium coli</i>	Balantidiasis
	<i>Cryptosporidium parvum</i>	Cryptosporidiosis
	<i>Entamoeba histolytica</i>	Amebiasis (amoebic dysentery)
	<i>Giardia lamblia</i>	Giardiasis
Helminths	<i>Ascaris lumbricoides</i>	Ascariasis
	<i>T. solium</i>	Taeniasis
	<i>Trichuris trichiura</i>	Trichuriasis
Viruses	Enteroviruses (72 type, polio, echo, coxsackie viruses etc.)	Gastroenteritis, heart anomalies, meningitis
	Hepatitis A virüs	Infectious hepatitis
	Norwalk agent	Gastroenteritis
	Rotavirus	Gastroenteritis

When determining the method to be used; Water quality, turbidity (particle quantity), water temperature, pH level and

type of pathogenic microorganisms in water should be taken into consideration. General water treatment applied for surface waters consists of three basic steps: flocculation or coagulation (the addition of aluminum sulfate or metal salts to the water to collect particles in water), sedimentation (It is the process of collapsing the water at the bottom of the tank with the effect of gravity of the particles coming together at the end of the first stage) and filtration (solid particles are removed from the water as a result of sedimentation with slow or rapid sand filters or with active charcoal filters) [21,22].

Drinking and use water is passed through the same steps and subjected to treatment. With good treatment, the number of bacteria in water can be reduced by 99.5%. Water is disinfected after pretreatment and its quality is increased. Disinfection is the process that is applied to neutralize the microorganisms in water. The efficacy of disinfection is defined by the action of killing 99% of the microbicide within 30 seconds. Disinfection is generally carried out by chemical, physical, mechanical methods or by radiation. The chemicals used in the disinfection process are chlorine and chlorine compounds, bromine and iodine compounds, ozone, phenol and phenolic compounds, alcohols, various dyes, soaps and synthetic detergents, ammonium compounds, hydrogen peroxide, various alkalis and acids. The use of heat and light (especially ultraviolet) are physical disinfection methods. Partial reduction of microorganisms is possible by mechanical processes such as precipitation, flocculation and filtration. Gamma rays from radioisotopes such as cobalt 60 are also used in water and wastewater disinfection [20-25]. Water disinfection methods were shown in Table 2.

Water disinfection methods (Table 2)

Table 2: Water disinfection methods

Chemical Methods	<ul style="list-style-type: none"> • Chlorine and chlorine compounds • Brom • Iodine • Ozone • Phenol and phenolic compounds • Alcohols • Heavy metals • Stains • Soaps and detergents • Ammonium compounds • Hydrogen peroxide • Peracetic acid
Physical Methods	<ul style="list-style-type: none"> • Temperature • Light (ultraviolet and sunlight) • Sound waves

Mechanical Methods	<ul style="list-style-type: none"> • Sand holder • Pre-sedimentation • Activated sludge system • Chemical precipitation • Stabilization pools • Trickle filter
Radiation	<ul style="list-style-type: none"> • Gamma rays • High energy electron beam

Generally, few disinfection techniques can be used in public health practices. A disinfectant needs to carry some properties in order to be used in drinking and potable water disinfection. It should be suitable for the removal of pathogenic organisms in the expected temperature range and the contact time provided in the composition and quantity of water to be disinfected, durable, economical and easy to use; easy, accurate and patriarchal analysis of the disinfectant should be possible in order to control disinfection time and effectiveness. One of the most important features of the disinfectant applied to the dose, does not show toxic properties. For this purpose, chlorination, UV and ozone are suitable for disinfection of large water bodies [17-25]. Others are suitable for environments where small water bodies or toxicity from disinfectants are ensured. Apart from chlorine and some compounds, there are some limitations in the use of other disinfectants and disinfection methods in drinking water treatment plants. For this reason, a very large percentage of disinfection processes are done with chlorine in water treatment plants. Disinfection with chlorine is the most widely used disinfection method in our country [26-30]. However, compounds that make cancer by adding chlorine to water (monochloro, dichloro and trichloroacetic acid structures) are known as carcinogenic effective disinfection by-products. "Swimming Asthma" caused by inhalation of by-products of chlorine (trihalomethanes) used in swimming pools has been observed especially in young children [31-34].

Disinfection By-Products (DBP's) are defined as the structures formed as a result of the reaction of organic or inorganic structures in the chemical composition of water with disinfectants. Factors affecting water disinfection; contact time, type and concentration of chemical disinfectant, density and structure of physical disinfectant, temperature, number of microorganisms, microorganism type and characteristics of water Table 4 [35].

Major factors affecting disinfection (Table 3)

Water must be protected from any contamination, especially microbiological contamination, during the storage and distribution (network system) phases following water treatment operations. In addition to the microorganisms that may come from outside, a very thin layer of microorganisms, often called biofilm, develops in the water tanks and distribution pipes. The most effective method used to protect treated water from all these microbiological contamination sources is chlorination before dispensing. No residual preservation method has yet to be proven, except for chlorination. Especially in

regions and countries where the integrity of the water distribution network is not fully ensured and water leaks from the network are present, chlorination is vital [7,36-38]. Conventional disinfection methods were shown in Table IV.

Table 3: Major factors affecting disinfection

Type of disinfectant	Disinfection efficiency depends on the type of chemical used. Each disinfectant has a separate strength and property. Some disinfectants such as ozone, chlorine dioxide are stronger oxidants than chlorine
Type and number of microorganisms	The resistance of microbial pathogens to disinfectants varies greatly. Spore-forming bacteria are more resistant to disinfectants than vegetative bacteria. Microorganisms are resistant to disinfectants in the following order. Vegetative bacteria-enteric viruses-spore-forming bacteria- protozoal cysts
pH and temperature	The pH and temperature of the environment are the most important factors affecting the effectiveness of disinfectants.
Contact time and disinfectant concentration	Pathogen inactivation with disinfectants increases with time and takes place with first order kinetics.
Physical and chemical interference	Inorganic and organic nitrogen compounds, iron, compounds such as manganese and hydrogen sulfide interfere with disinfection. Dissolved organic compounds increase the chlorine requirement and their presence decreases the disinfection efficiency. The turbidity in the water consists of microbial cells and inorganic (silt, clay, iron oxide, etc.) and organic matter.

Conventional disinfection methods (Table 4)

All chemical disinfectants (chlor-Cl₂, monochloramine-NH₂Cl, ozone-O₃, chlorine dioxide-ClO₂) are known to form various by-products. The most important precursors are natural organic matter and bromide. By-product formation; pH, temperature, time, disinfectant type, dose and dose, contact time, application point of disinfectant etc. depends on the parameters. Some by-products are halogen-substituted by-products, while others are by-products of oxidation. Halogenated organic by-products are formed by the reaction of natural organic material (NOM) with free chlorine and free bromine. The free chlorine can reach water directly with chlorine dioxide or chloramines as primary or secondary disinfectant. Free bromine is formed by oxidation of bromide ions in water. [2,25-29,31].

Formation of halogenated disinfection by-products; it depends on the type and concentration of the natural organic material, the type and dose of the oxidant, the time, the concentration of bromide ion, the pH, the concentration of organic nitrogen and the temperature. Organic nitrogen causes the formation of nitrogen-containing disinfection by-products such as haloacetonitrile, halopicrin and cyclones. Non-halogenated disinfection by-products are also the result of the interaction of organic compounds in water with strong oxidants. Most oxidizing by-products are biodegradable and are present in the treated water as biodegradable dissolved

organic carbon (BDOC) and as assimilable organic carbon (AOC). Free chlorine and free bromine are produced in chloramine. Therefore, the formation of the disinfection by-products that occur in chlorination is also expected here. However, they are in lower concentrations [2,25-29,31]. Chloramines are weaker oxidants than chlorine and are more likely to be involved in chlorine substitution reactions than oxidation reactions, similar to chlorine. Substitution reactions are particularly common with organic nitrogen compounds. The chlorinated aldehydes, chlorinated acids and chlorinated ketone by-products were determined when chloramine was applied to the waters containing fulvic acid [32-38]. Products produced by ozonation of drinking water include simple aldehydes, small molecular weight aliphatic acids, some keto-acids, hydroxy-acids, organic peroxides and benzene polycarboxylic acids. It is suspected that only this group of peroxides, bromo-organics and aldehydes may be harmful to human health [39-43]. In particular, formaldehyde may be a product that is always present. Some of these by-products (such as peroxides, formaldehyde) can be consumed by slow reaction with other components in water. When water containing high amounts of bromide is ozonated, the formation of brominated organic by-products will occur. This is the result of oxidation of bromide to hypobromous acid followed by reaction of natural organic matter with hypobromous acid. At typical pH and ozone dose values, approximately 7% of the bromide in the raw water is converted to total organic bromine (TOBr). The formation of TOBr increases with high bromide levels, low pH and high ozone dose. It has already been recognized that ozone, under certain conditions, has produced new precursors and caused an increase in THM formation. It has long been known

that ozone destroys THM precursors in drinking water [44-50]. Studies have shown that the need for chlorine decreases with pre-ozonation. After ozonation, it was observed that chlorination at low pH caused the most decrease in THM formation. In systems with high pH chlorination (above pH 8.5), it is possible to see a clear increase in THM formation. In water treatment applications, there is little literature on UV-related by-products [51-54]. In 1994, the Montgomery Watson Company reported that trihalomethanes were not formed if UV radiation was applied to recovered wastewater. Significantly, it reduces aldehyde formation and does not emerge from other FDIs [55]. The application of UV radiation to surface waters under certain conditions highlights a number of reduction reactions and as a result, bromate can be reduced to bromide. Since bromate absorbs UV radiation only within the 200-240 nm range, these reactions cannot be initiated with low-pressure mercury lamps. Medium pressure lamps can cause these reactions [56,57]. In a study conducted by AWWA to assess the effects of low-pressure mercury lamps on by-product formation, no formation of bromate or bromine by-products was observed in any of the groundwater samples [55]. In addition, no change in bromate concentrations was observed in samples containing bromate before UV. In the same study, UV radiation was observed to form low levels of formaldehyde in most surface water samples. The highest formaldehyde concentrations were found in untreated surface waters. Water exposure to water may result in the formation of ozone or radical oxidants. Formaldehyde is a common ozonation by-product. Consequently, conventional UV technology is a promising method which does not constitute a by-product, which may be an alternative to other methods.

Table 4: Conventional disinfection methods.

Boiling process	If the water is boiled for 15-20 minutes, the bacteria it contains are inactivated. This method is often used in homes. Heat disinfection is a very expensive method for large-scale applications, but is widely used in the food industry. Heat disinfection is associated with heat resistance of microorganisms or spores.
Acid and alkali addition	Water with pH <3 or pH > 11 is toxic to many bacteria and can be used in pathogen inactivation. Disinfection of drinking water with the addition of acid and alkali is not a common practice. However, it is a spontaneous phenomenon in lime-soda softening processes. Addition of lime to water reduces some microorganisms in water. Requires long contact times. Cationic detergents are used as disinfectants in health institutions. Cationic detergents are strong disinfectants and anionic detergents are poor disinfectants.
Potassium permanganate	It is a strong oxidizer and disinfectant. However, the removal rate of permanganate E.coli is lower than that of ozone and chlorine. Therefore, it is very rare to use it for disinfection in drinking water treatment plants. It does not form taste, odor and toxic compounds in water
Bromine, Iodine, Chlorine	<p>Bromine; It is a weaker disinfectant than chlorine. The monobrom amine formed due to the fact that it is a strong bactericidal and tribromamine formation in water containing ammonia is used for small applications in swimming pools</p> <p>Iodine; It does not react with organic substances as easily as chlorine. It is an advantageous disinfectant due to its high disinfection power. Iodine does not form iodamines with ammonia; however, it oxidizes ammonia. After disinfection, the residual iodine is stable and it is also an advantage that it does not create odor. The fact that the effects of water treatment is not well known is 10-15 times more expensive than chlorine. It is not used for possible effects on the thyroid gland.</p> <p>Chlorine; It is preferred as disinfectant in all underground and surface water treatment systems. The attractive properties of chlorine; Effectively inactivate a large part of the water pathogens, easy to measure, controllable residues and economic is to leave. However, there are factors limiting the use of chlorine. These disadvantages are;</p> <ul style="list-style-type: none"> • Reacts with naturally occurring organic and inorganic compounds in water and forms undesirable disinfection by-products • Requires special treatment of hazardous compounds due to chlorine use • High chlorine doses cause taste and odor problems.

In conclusion, chlorination is the most common, effective and cheapest disinfection method of water. At the same time, it is an effective microbiocide against all water-borne pathogens, although it can cause by-products after disinfection of drinking or pool water disinfection. In general, other disinfection of disinfection are used as a supplement.

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