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A Review on Drinking Water Treatment with Disinfectant

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ABSTRACT- The majority of the world's natural water sources are not always safe to consume untreated. Raw water from rivers, lakes, ponds, and groundwater can include microorganisms. Waterborne diseases can be contracted by consuming it when pathogens in the water are spread through a drinking water distribution system. As it guarantees that water is free of dangerous microorganisms that cause water-borne diseases, disinfection is an essential water treatment technique. Different disinfection techniques are used to inactivate germs to fight waterborne illnesses. The primary goal of this essay is to describe various disinfection techniques, their applicability, limitations, and factors affecting the disinfection process. Chlorine by products and the effects of chlorine by products on people.

KEYWORDS- Raw Water, Disinfection, Pathogens, Chlorine by Products and Distribution System.

I. INTRODUCTION

Most of the world's natural water sources are not usually fit for drinking untreated. For pure water in the past, people relied on the sun, wind, soil filtration, and time. The intense use of the water resources made water treatment necessary because of the physical, chemical, and/or biological impurities that result from human activity, animal activity, and natural phenomena. Raw water from rivers, lakes, and groundwater contains microorganisms. Even though not all microbes are dangerous to human health, some of them have the potential to make people sick. Numerous diseases, such as hepatitis, cholera, typhoid fever, dysentery, and others may be brought on by the presence of microorganisms in water. Pathogens are what they are. Waterborne diseases can be contracted by consuming it when pathogens in the water are spread through a drinking water distribution system.

Public health could be at risk from drinking water supplies that have human enteric viral viruses present. The severity of the diseases caused by enteric viruses can range from self-limiting diarrhea to meningitis and even death (Alyaa M. Zyara et al., 2016). Although the conventional drinking water treatment process is generally quite effective at removing viruses from water, some may still survive and enter the distribution system and cause epidemics (Le Chevalier et al., 2004). Removal of the viruses depends on virus type and treatment process performance (Kukkula et al.,1999&Maunula et al.,2005).

The pathogens must be eliminated in order to make the water safe to consume and to fight waterborne diseases. Disinfectants are substances that are used to destroy pathogenic bacteria, and disinfection is the process of doing so (S.K. Garg). To inactivate or eradicate germs, many disinfection techniques are employed in conjunction with other water treatment procedures, including as Water that is fit for human consumption is produced through simple sedimentation, sedimentation assisted by coagulation and filtering, and disinfection. A critical stage in the creation of safe drinking water is water disinfection. Disinfection is the deliberate eradication of pathogens through the use of chemical or physical means. Disinfection differs from sterilisation in that it does not result in the total eradication of all organisms during the process (Bergman et al., 1976). The presence of a disinfectant residual is more crucial for large distribution systems with long retention times or when there is infrequent placement of distribution system pipes. Some disinfection processes also provide a disinfectant residual to prevent microbial regrowth during water distribution (Rosario-Ortiz et al., 2016).

The adoption of water supply disinfection as a public health intervention has significantly decreased the number of individuals getting sick from drinking water in the developed countries. However, if applied improperly or in excess, several of these disinfectant chemicals might result in the creation of disinfection by-products during the water treatment process. When disinfection agents interact with organic or inorganic substances, byproducts of disinfection are created. According to research, human exposure to these byproducts may have a negative impact on health. (Schoenen, D. 2002)

II. IMPACTS OF DISINFECTANT ON DRINKING WATER

The procedure of disinfecting water is crucial because bacterial contamination of the water can spread a number of diseases and related epidemics, wreaking havoc on daily life. Although the presence of turbidity, color, minerals, etc., may not be hazardous, the presence of even one dangerous organism can be. Thus, making water disinfection the most crucial process.

Natural calamities like earthquakes or extreme weather events (floods) can disrupt water distribution systems in various ways and introduce germs into various locations across the system. Terrorist attacks utilizing chemical or biological agents that could harm water customers' health are examples of malicious threats. It is possible for contaminants to enter the network even when it is working normally, whether as a result of maintenance that was planned or unplanned or even during routine operations (for example, because of leaking pipes that allowed substances from the ground to enter the network) (Kanakoudis, V. et al,2007). Sometimes, water supply pipes are above sewer networks, therefore possible leaks in both networks could be the reason why the water is contaminated.

So protecting water safety is a top responsibility right now. Disinfection guarantees that existing bacteria in water are not only eliminated or rendered inactive in water treatment facilities, but are also killed as soon as they enter the distribution system. Disinfectants also stop water from becoming contaminated while it travels from the treatment facility to the location where it will be consumed. Disinfectants that can maintain a long-lasting sterilising action and provide some protection against recontamination. The disinfectants should be inexpensive, non-irritating to the tongue, and quantifiable by straightforward testing (S. K. Garg).

A good disinfectant must be poisonous to microorganisms at concentrations much below toxic thresholds for people and higher animals, as well. It should also have a quick kill time and be persistent enough to stop organisms from regrowing in distribution systems (Peavy et al (1985).

A key component of water treatment is disinfection, which guarantees that the water is free of dangerous bacteria that might cause diseases that are spread through water. After disinfection was added to water treatment in the United States, the incidence of cholera, typhoid, and amoebic dysentery all decreased by 90%, 80%, and 50%, respectively (Ohanian, E.V 1990).

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III. METHODS OF DISINFECTION

A. Physical Methods

Boiling, U-V radiation, electromagnetic radiation, ultrasonic sound, and activated carbon are the principal physical means of disinfection.

These techniques are only used in a few places since they are extremely expensive and provide no lasting protection against potential future contaminations.

1) Boiling

An easy and fundamental way of disinfection is boiling. Boiling water for a long time can kill any bacteria present. To eradicate all bacteria, water is heated to boiling point and kept there for 15–20 minutes (Fair G.M et al, 1968). Temperatures above 65 °C result in rapid deaths of bacteria in less than 1 minute per log (90%) reduction. At temperatures between 60 °C and 65 °C, viruses become inactive, however more slowly than bacteria. As temperatures rise over 70 °C, poliovirus and hepatitis A are inactivated by more than 5 logs (99.999% reduction) in less than a minute (WHO,2011, Guidelines for Drinking Water).

2) UV Radiation

A cell exposed to UV light may be killed, have its growth stunted, and have its genetic makeup altered (Nicki Pozos et al., 2004). UV rays, which are often seen in sunshine, can also be created by running an electric current through mercury that is contained inside a quartz bulb. Water must repeatedly circulate around the quartz bulbs releasing UV Rays in order to receive treatment. The UV spectrum has a range of 100 to 400 nanometers (nm), with 200 to 280 nm being the most effective range for killing germs. The four main types of UV light are UV-A, UV-B, UV-C, and vacuum UV.

UV-C, often known as germicidal light, falls between 240 and 280 nanometers (nm). For many purposes, disinfection utilizing ultraviolet light in the UV-C spectrum may be preferable. The UV dosage, which can be calculated from the known UV intensity, exposure time, and water flow rate, is the main component of a UV treatment system. The water should not be deeper than 10 cm or so over the bulb because the rays can only efficiently penetrate this level. Since no chemicals are added to the water during the UV disinfection process, the water does not acquire any additional flavour or odour.

3) Electromagnetic Radiation

An electric and magnetic disturbance known as electromagnetic radiation travels through space at the speed of light (2.998 108 m/s). Radio waves, microwaves, infrared, ultraviolet, gamma, and x-rays are all types of electromagnetic radiation. Cosmological sources (such as the sun and stars), radioactive substances, and manmade gadgets are some examples of sources of EM radiation. The dual wave and particle character of EM is evident. High ionising power is a characteristic of both X-rays and gamma rays. Almost anything they collide with tends to become ionised. The germicidal characteristics of radiation between 0.2 and 0.3 J peak at a wavelength of 0.26 J (2600 Ao). Therefore, the source needs to be close to the medium. It is best to expose water in thin sheets. The main radiation source is cobalt 60 (Co60) (Bhagwatula. A, 2000).

4) Ultrasonic Sound

Ultrasounds are defined as sounds with a frequency of at least 20 kHz (or ultrasonic sound). Water disinfection can be accomplished using ultrasound. Water bubbles are produced by ultrasound through a process known as cavitation. The gas inside the bubbles experiences a brief period of high temperature and high pressurisation as they burst. The degradation of organic pollutants is possible at these temperatures and pressures.

Cavitation is a complicated process that depends on the quantity and makeup of bubbles and cavities over an extended period of time. Cavitation happens when driving frequencies of roughly 20 kHz are utilised and a threshold of 0.06-0.1 MPa surpasses the acoustic pressure amplitude for distilled water (Eskin & Eskin, 2014).

There is no germicidal impact of ultrasonic vibrations in and of themselves. It has been proven that 400 KHz ultrasonic waves may completely sterilise an object in 60 minutes. Within 2 seconds, a very significant reduction in bacterial population is seen (Mohmoud Farshbaf Dadjour 2006).

5) Activated Carbon

A group of compounds collectively known as "activated carbon" are distinguished chiefly by their sorptive and catalytic characteristics. A variety of carbonaceous materials can be used to make activated carbon, which is then treated to improve its adsorptive qualities. Bituminous coal, bones, coconut shells, lignite, peat, pecan shells, petroleum-based residues, pulp mill black ash, sugar, wastewater treatment sludge, and wood are a few resources that are frequently used to generate activated carbon (Weber, 1972).

In a water treatment plant, GAC is often utilized after the coagulation and sedimentation procedures and, frequently, after the initial disinfection phases, during which chemical reactions can happen. In addition, water is frequently disinfected before it enters the GAC absorbers to stop bothersome biological growths.

Typically, water is pumped downward through densely packed GAC beds. The number of particles being removed and the degree of microbial development determine how frequently backwashing is necessary. A water supply is typically treated with GAC post-disinfection to lower the overall bacterial count, some of which may be present due to microbial growths in adsorbers. In order to prevent water pollution, a sufficient amount of disinfectant is often applied to ensure a residual in the distribution system. Because aqueous oxidants employed in preliminary disinfection stages would typically be removed by reaction with the GAC, post disinfection is required in addition to pre disinfection.

In rare cases, some synthetic resins may be employed in place of GAC or in combination with GAC to produce water with the necessary quality. The main distinction between resins and GAC is that although resins are typically thermally regenerated, GAC is frequently regenerated by the application of aqueous solutions of acids, bases, and/or salts, non-aqueous solvents, or steam. Resins typically require a pre-treatment phase, which depends on the type of resins (Drinking Water and Health, Volume 2, 1980).

B. Chemical Methods

Chemical techniques of disinfection involve adding chemicals to the process of disinfection. The following substances are used in the process of disinfection: (1) Ozone (2) Lime Potassium permanganate, metallic ions, other halogens, hydrogen peroxide, and acid and alkali round out the list

1) Treatment with ozone

Ozone gas is a faintly blue gas of pungent odor, and an excellent disinfectant. Ozone gas is unstable allotropic form of oxygen, with each of its molecule containing three oxygen atoms. Ozone has can be produced by passing high electric current through a stream of airing closed camber, under the following chemical reaction

$$\underset{\text{Oxygen molecule}}{3\,O_2} \xrightarrow{\text{Under high electric arc voltage}} \underset{\text{Ozone molecule}}{2\,O_3}$$

The developing oxygen is a potent oxidizer that clears the water of both bacteria and organic waste. A sterile chamber with water inlets and outlets as well as an ozone inlet is used to create and bubble ozone gas through water throughout the treatment process.

2) Treatment with lime

According to the "CPHEEO: Manual on water supply and treatment," lime is typically used in water treatment facilities to soften the water. If too much lime is added to the water, the bacteria will also be killed. It has been discovered that adding 14–43 ppm of lime to extremely polluted streams can remove 99.3–100% of the bacterial load. Lime increases water's pH value, making it significantly more alkaline. Bacteria are shown to suffer under these excessively alkaline environments. That will either entirely or partially eliminate the bacterium. 99.9 to 100% of the bacteria are eliminated when lime raises the pH of water to around 9.5.

3) Treatment with Potassium Permanganate

Potassium permanganate is affordable, practical, and very beneficial. In addition to being a powerful oxidising agent used to remove iron and manganese, potassium permanganate also has germicidal properties. It causes the organic material in water to oxidise. It is additionally employed as an algicide and to purge water of color and iron.

A tiny amount of potassium permanganate must dissolve in water and be extensively incorporated into the water in order to treat well water sources. Pink colouris produced by the addition of potassium permanganate. If the pink color fades, there is organic matte in the water, and more potassium permanganate needs to be added until the pink color is maintained.

4) Treatment with Metalic Ions

Some metallic ions, including those of silver, mercury, copper, and Fe (VI), have the ability to disinfect (Min Cho, 2006). By passing the water through a tube holding solid silver electrodes that are connected to a direct supply of 1.5 volts, metallic silver ions are introduced into the water using this method. With a dosage of 0.05–0.1 mg/l, it will kill the pathogens during a contact time of 15 minutes to 3 hours.

The water treated with silver ions does not taste or smell bad. Since it is an extremely expensive treatment, it cannot be used in public supplies. Before utilising silver ions, suspended organic debris and hydrogen sulphidemust be eliminated by pre-treatment since they hinder the effectiveness of bacterial eradication.

5) Acids and Alkali

By addition of Acidic or alkaline water becomes either acidic or alkaline (Fair, G. M., 1968). The growth of microorganisms is dependent on the pH of the water. pH of water and bacteria cannot survive at very low or very high ph. By adding small amount of acid or alkali and continuous stirring will reduce or increase pH of water. After destruction of pathogen the pH of water should be brought back to neutral. Although, disinfection of water can beach ivied using this method, theme thuds not practicable.

IV. FACTORS AFFECTING DISINFECTION

Chlorine creates chlorination byproducts (CBPs) when it combines with the organic content in water, which frequently modifies the water's overall chemical composition. Water contains some organic matter that is naturally occurring, as well as anthropogenic contaminants, bromide, and iodide. When a chemical disinfectant like chlorine is added to water, it tends to react with the organic matter to create disinfection by products (DBPs), which are known to have negative health effects on people (S. D. Richardson, 2011). Numerous disinfection byproducts are notorious for having teratogenic, carcinogenic, mutagenic, cytotoxic, or genotoxic properties. However, a number of variables, including pH, temperature, source water properties, disinfectant type, and residence period, affect the development of DBPs (S. W. Krasner, 2009).

Water disinfection is a crucial step in the treatment process for ensuring the safety of drinking water, but it poses a risk to chemical safety since it produces disinfection byproducts during chlorination, zonation, and chlorination with organic natural matter. More than 600 DBPs have been identified and verified in drinking waters since the early 1970s, according to studies showing that chlorination creates potentially dangerous DBPs (S. E. Hrudey et al., 2012).

Trihalome thanes (THMs), halo acetic acids (HAAs), halo acetaldehydes (HALs), halo ketones (HKs), and nitrogenous DBPs (N-DBPs), such as halo acetonitrile's (HANs), halo nitromethanes (HNMs), and halo a ceramide, are among the types of DBPs that have been identified (T. Bond et al, 2011).

According to toxicological research, several DBPs have negative effects on reproduction or development and can induce cancer in the liver, kidney, and/or large intestine of animals (Boorman et al. 1999). Epidemiological studies have found a marginally higher incidence of bladder, colon, and rectal cancers in people who had long-term exposure to chlorinated surface waters (Villanueva et al. 2004). Additionally, several epidemiology studies have demonstrated a link between consuming water that has been chlorinated and harmful reproductive or developmental health outcomes, like spontaneous abortion or fetal abnormalities (Nieuwenhuijsen et al. 2000).

To establish whether there are adverse effects due to by product compounds in drinking water is difficult, as they exist in low concentrations and in conjunction with many other chemicals. Obtaining estimates of a person's exposure in utero to such agents is dependent not only on the type of disinfection process of the mother's residential water source, but also on the person's consumption of tap water, the level of toxicants present in the water supply during the critical exposure period, and exposure through pathways other than ingestion such as inhalation of and dermal contact with and uptake of compounds while showering, bathing, and swimming (Levesque Betal, 1994 & Weisel C Pet al.,1999).

V. FACTORS AFFECTING DISINFECTION

Turbidity: If the water is more turbid, the effectiveness of the disinfection process is reduced, which impacts the chlorination process. The process of disinfection is impacted by turbidity and dissolved materials in water. Turbidity is caused by colloids, which lessens the interaction of microbes with chlorine (Shreoder, 1997).

- Metallic compounds: Iron (Fe) and manganese (Mn) both increase the quantity of chlorine that is used. Therefore, it is necessary to eliminate iron and manganese before adding chlorine to water.
- Ammonia compounds: Compared to freely available chlorine, mixed ammonia and chlorine compounds are not effective disinfectants.
- The pH of water controls how much hypochlorous acid (HOCl) and hypochorite ion (OCl-) are present in solution. For E. coli, HOCl is 80 times more effective than OCl-. More OCl- ions are formed when the p H value of the water rises. Chlorination is less effective when the pH of the water is raised. Contrarily, the killing of bacterial, viral, and protozoan cysts by chlorine dioxide typically occurs at higher pH levels (G. Bitton, 2011 & M.D. Sobsey).
- Water temperature: Raising the temperature of the water will make disinfection more effective.
- Time of Touch: The percentage of pathogens killed depends on how long the chlorine is in contact with the bacteria. Usually, 10 minutes are needed for free chlorine and 60 minutes are needed for combined chlorine.

VI. CONCLUSIONS

In some particular circumstances, the methods presented in this paper seem like appealing disinfection techniques. They do, however, have drawbacks like cost and a lack of lasting impact. As a result, both historically and currently, chlorine is regarded as the preferred option. The limitations of employing chlorine as a disinfectant and the need for substitute disinfectants have been shown through technological advancements and development. In wealthy nations nowadays, UV radiation and ozone are used. However, because of a lack of resources, the use of these pricey procedures is restricted in underdeveloped nations.

DBPs, or disinfection byproducts, have drawn a lot of attention because of their potential link to cancer, particularly bladder and rectal cancer. Low birth weight, preterm delivery, spontaneous abortions, stillbirths, and birth defects—specifically birth defects of the central nervous system, major cardiac defects, oral cleft, respiratory, and neural tube defects—are the outcomes of interest associated with chlorination disinfection byproducts (DBPs). The best way to regulate DPBs is to get rid of the precursor before the disinfectant reacts with it.

CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

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