International Journal of Scientific Research in Science and Technology
Print ISSN: 2395-6011 | Online ISSN: 2395-602X (www.ijsrst.com)

Chlorination an Important step of Disinfection for Treatment of Drinking Water - An Overview

Dr. Nripendra Kumar Singh
Environment Specialist, NNP, PHED, Patna, Bihar, India

Article Info
Volume 7, Issue 4
Page Number: 380-387
Publication Issue :
July-August-2020

Article History
Accepted : 15 Aug 2020
Published : 25 Aug 2020

ABSTRACT

Microorganism can be found in all source of water i.e. rivers, lakes and groundwater. All microorganisms are not harmful to human health but some are may cause diseases in humans which called pathogen. Pathogens present in water can be transmitted through a drinking water distribution system, causing waterborne disease in those who consume it.

Boiling and chlorination are the most common water and wastewater disinfection processes in use throughout the world. Boiling is primarily used in rural areas in developing countries to eliminate living organisms, especially bacteria, present in the water. It is also used in emergencies when other, more sophisticated methods of disinfection are not available. Prior to the development of chlorination, boiling was the principal method used to kill pathogenic organisms. Chlorination has become the most common type of wastewater and water disinfection. It should be to kill harmful organisms, and generally does not result in sterile water (free of all microorganisms).

Keywords : Chlorination, Boiling, Microorganisms, Elemental Gas, Sodium Hypochlorite Solution

I. INTRODUCTION

Chlorine is a chemical used in industry and in household cleaning products. Chlorine is among the ten highest volume chemicals made in the United States. At room temperature, chlorine is a gas. It has a yellow-green color, and a pungent, irritating odor similar to bleach. Usually, it is pressurized and cooled for storage and shipment as an amber-colored liquid. Chlorine does not catch fire easily, but may combine with other common substances to form explosive compounds. Some facts about Chlorine are:

- Atomic number: 17
- Atomic symbol : Cl

- Atomic weight : 35.453
- Density: 3.214 grams per cubic centimeter
- Phase at room temperature: Gas

History of Chlorination

Chlorine was first discovered in Sweden in 1744. At that time, people belived that odours from the water were responsible for transmitting diseases. In 1835, chlorine was used to remove odours from the water, but it wasn't until 1890 that chlorine was found to be an effective tool for disinfecting; a way to reduce the amount of disease transmitted through water. With this new find, chlorination began in Great Britain and then expanded to the United States in 1908 and Canada by 1917. Today, chlorination is the most popular method of disinfection and is widely used for water treatment all over the world.

Chlorination

- Chlorination is the process of adding chlorine to drinking water to disinfect it and kill germs. Different processes can be used to achieve safe levels of chlorine in drinking water. Chlorine is available as compressed elemental gas, sodium hypochlorite solution (NaOCl) or solid calcium hypochlorite ($Ca(OCl)_2$.
- In particular, chlorination is used to prevent the spread of waterborne diseases such as cholera, dysentery and typhoid.
- Microorganisms are microscopic living organisms found in most environments on earth, including water. Microorganisms may be naturally present in water sources, but may also be introduced through human activities (e.g. the discharge of human and animal wastes).
- Some microorganisms may be harmful to human health (called pathogens). If water is consumed without adequate treatment to remove pathogens, it may cause life-threatening disease, such as diarrhoea. Disease that is spread by water is referred to as waterborne disease.

Microorganisms commonly associated with waterborne disease include:

- Bacteria (e.g. *Escherichia coli*, *Vibrio cholerae*);
- Viruses (e.g. Hepatitis A, poliovirus A); and
- Protozoa (e.g. *Cryptosporidium*, *Giardia*)..

Types of Chlorination

- **Plain Chlorination:** This process includes only the chlorine treatment and no other treatment has been given to the raw water.
- **Pre-Chlorination:** Pre- chlorination is the process of applying chlorine to the water before filtration or sedimentation.

- **Post Chlorination:** post chlorination is the normal standard process of applying chlorine at the end, when all other treatment has been completed.
- **Double Chlorination:** This process indicates the water has been chlorinated twice as pre and post chlorination.

Properties of Chlorine

Chlorine exists as a solid (e.g. powder), liquid or gas. Key properties of chlorine with relevance to drinking-water disinfection include the following:

- Chlorine is very chemically reactive, reacting with organic material, microorganisms, metals, pipe material and pipe fittings;
- Chlorine liquid is volatile, meaning once exposed to air, the chlorine may be lost from the water phase and go into the air;
- Chlorine has a distinctive, characteristic taste and odour, which may be detected by individuals when smelling or drinking the water;
- Chlorine is corrosive, meaning it can cause severe irritation and chemical burns to human tissues such as skin, as well as damaging material such as pipes; as such, chlorine must be stored and handled carefully and
- Chlorine may remain in the water after disinfection has occurred; this may protect drinking water from recontamination by harmful microorganisms during storage and distribution to the consumer.

How to express the strength of chlorine

Chlorine gas typically contains pure chlorine. However, chlorine powder and liquid do not contain pure chlorine, and are mixed with other substances (e.g. calcium, sodium or water). Because of this, the strength of chlorine in chlorine powder or chlorine liquid is referred to as the concentration of chlorine in that substance. Typically, this is expressed as the percentage (%) of active chlorine present in following table.

Table 1. Strength & Stability of chlorine Gas, chlorine powder and chlorine liquid

	Chlorine Gas	**Chlorine Powder**	**Chlorine Liquid**
Appearance	Green Yellow Gas	White Powder, granule or tablet	Pale Yellow to clear water
Strength	100% active Chlorine	30 to 70 % Chlorine	1 to 15% Chlorine
Stability	Most Stable over time	May lose strength over time	Less stable than Chlorine Powder

Reaction of Water

When chlorine in the form of Cl_2 gas is added to water, two reaction take place: hydrolysis and ionization

$$Cl_2 + H_2O \Longleftrightarrow HOCl + H^+ + Cl^-$$

Because of the magnitude of this coefficient, large quantities of chlorine can be dissolved in water.
Ionization may be defined as

$$HOCl \Longleftrightarrow H^+ + OCl^-$$

The quantity of HOCl and OCl^- that is present in water is called the free available chlorine. The relative distribution of these two species is very important because the killing efficiency of HOCl is about 40 to 80 times that of OCl^-.

Free chlorine can also be added to water in the form of hypochlorite salts. The pertinent reactions are as follows:

$$Ca(OCl)_2 + 2H_2O \longrightarrow 2HOCl + Ca(OH)_2$$
$$NaOCl + H_2O \longrightarrow HOCl + NaOH$$

Chlorine forms hydrochloric acid when added to water which causes chemical reactions which deactivate contaminants and reacts through oxidization with micro-organisms, organic matter, manganese, iron and hydrogen sulphide.

Three things can happen when chlorine is added to water:

1. Some chlorine reacts through oxidization with organic matter and the pathogens in the water and kills them. This portion is called consumed chlorine.
2. Some chlorine reacts with other organic matter and forms new chlorine compounds. This portion is called combined chlorine.
3. Excess chlorine that is not consumed or combined remains in the water. This portion is called free residual chlorine (FRC). The FRC helps prevent recontamination of the treated water.

Ct concept for disinfection

During the disinfection process, chlorine requires time to kill or inactivate microorganisms present in drinking-water this is referred to as contact time. The Ct value is the product of the chlorine concentration (C) and the contact time (t) with the drinking-water. The Ct value required for effective disinfection is dependent on several factors, including the combined influences of:

(1) The concentration of chlorine in the water;
(2) The temperature of the water; and
(3) The pH of the water.

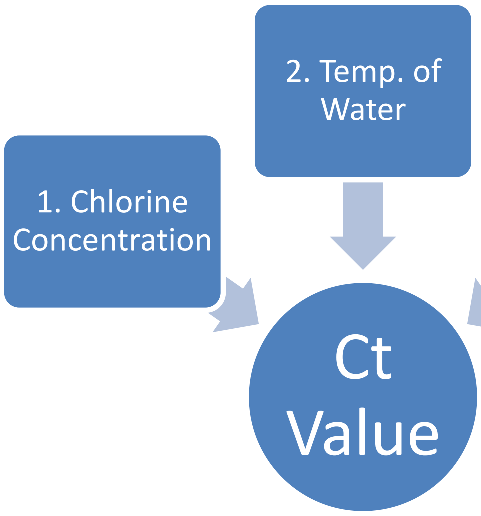

Fig 1 : Factors Affecting Ct Value for disinfection

Calculation of Ct Value

Ct (min.mg/L) = Residual chlorine (mg/L) x Contact time (min.)

Where

- The residual chlorine is the residual concentration of chlorine in the water.
- The contact time is the amount of time there is contact between the chlorine and the water.

Conditions required for effective chlorination

For effective primary chlorination of drinking-water, the following ideal conditions are recommended:

1. Turbidity - < 1
2. pH - < 8.0
3. Minimum Contact time – 30 minute

Chlorine Demand

This organic and inorganic material may be referred to as chlorine reactive substances. Chlorine is used up (or consumed) during these reactions, so the concentration of chlorine decreases.

The amount of chlorine that is consumed through the reaction between chlorine and the chlorine reactive substances present in the water is called the chlorine demand.

Calculation of Chlorine Demand

Chlorine demand (mg/L) = Actual chlorine dose (mg/L) - Residual chlorine (mg/L)

Once the chlorine demand has been satisfied, and the disinfection reactions are complete, the remaining chlorine is referred to as the total chlorine. Total chlorine consists of:

- **Combined chlorine:** This is the chlorine that has reacted with organic material and nitrogen compounds (such as ammonia) to form weak disinfectants; and
- **Residual chlorine:** The free chlorine that is remaining and available for disinfection, and protects the water from recontamination from microorganisms to a degree.

Calculation of Chlorine Dose

$$\text{Actual chlorine Dose (mg/l)} = \frac{\text{Chlorine dose rate (mL/h) x Chlorine liquid concentration (\%)]} \div 100}{\text{Flow rate } (m^3/h)}$$

Where:

- The chlorine dose rate is the actual chlorine dose being delivered by the chlorine dose pump.
- The chlorine liquid concentration is the percentage of active chlorine present in the chlorine liquid solution.
- The flow rate refers to the flow of water.
- The division by 100 is a standard unit conversion factor.

Chlorine Decay

Chlorine decay explains the decrease in chlorine concentration that may be observed as water passes through a water distribution network.

The rate and extent of chlorine decay will depend on a number of factors, including:

- The level of chlorine reactive substances that are present in the treated water as well as the distribution network (organic and inorganic material);
- How long the water remains in the distribution system (the chlorine concentration decreases over time).

Safe handling and storage of chlorine

If chlorine makes contact with clothing material, remove the affected clothing
If chlorine:

- makes contact with skin, eyes, nose or mouth, immediately, rinse the affected area with running water for a minimum of 15 minutes
- is ingested or inhaled, drink water; do not induce vomiting
- Seek immediate medical assistance

Storage and stock management practices for chlorine

Over time, chlorine powder and liquid will begin to degrade and lose strength (Table 2). The rate of chlorine degradation may be accelerated through poor storage and stock management practices.

Table 2. chlorine degradation during storage (approximate)

	Type of Chlorine (% active Chlorine Concentration approx)	Loss of initial active chlorine Concentration (%)
Chlorine Powder	Bleaching Powder (35%)	5 to 18% after 40 days
	High test hypochlorite (70%)	
Chlorine Liquid	Sodium hypochlorite (15%)	50% after 100 days
	Sodium hypochlorite (10%)	50% after 220 days
	Sodium hypochlorite (5%)	50% after 790 days

To minimize the rate and extent of chlorine degradation, appropriate storage conditions should be in place, including:

- always store in a cool, dry, well ventilated place;
- store away from direct sunlight and excessive humidity and temperatures;
- store in corrosion resistant containers (for example, light resistant plastic [poly vinyl chloride; high density polyethylene]);
- keep all storage containers fully sealed when not in use;
- date and mark all stock upon receipt; and
- Use in first in, first out (FIFO) stock rotation principles (i.e., always using the oldest stock first).

Conclusion

Drinking water chlorination has virtually eliminated waterborne diseases such as cholera, typhoid and dysentery. Chlorine is the water treatment of choice because it is efficient, economical and easy to use. Moreover, drinking water chlorination ensures the presence of a residual disinfectant throughout the water distribution system from the treatment plant to the consumer's tap. For effective chlorination of drinking-water, the ideal conditions are recommended i.e. Turbidity: <1 NTU, pH: <pH 8.0 & Minimum contact time: At least 30 minutes contact time. To achieve a minimum residual chlorine concentration of 0.2 mg/L at the point of consumer delivery, residual chlorine concentrations in the distribution system may need to be above the aesthetic target residual chlorine concentration of 0.5 mg/L under certain circumstances. At all times, the

concentration of chlorine in drinking-water supplied to consumers should be not more than the IS: 10500 guideline value of 0.2 mg/L. To ensure adequate disinfection, the WHO recommends a minimum Ct value of 15 min. mg/L for disinfection when the pH of the water is <pH 8.

II. REFERENCES

[1]. Wastewater Engineering Treatment, Disposal and Reuse Third Edition, Metcalf & Eddy, Inc.

[2]. Principle and Practices of Drinking Water Chlorination: a guide to strengthening chlorination practices in small to medium sized water Supplies by WHO 2017.

[3]. Water Treatment Plant Design, Mc Graw Hills HAND BOOK, Fourth Edition.

[4]. Manual on Operation and Maintenance of Water Supply Systems, Central Public Health and Engineering Organization (CPHEEO Manual), Ministry of Urban Development, New Delhi.

[5]. Standard Methods for the Examination of Water and Wastewater, Sixteenth Edition, APHA.

[6]. Operation and Maintenance Manual for Rural water Supplies, Govt of India, Ministry of Drinking Water & Sanitation 2013.