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## REVIEW ARTICLE

### HEALTH EFFECTS OF CHLORINATED WATER: A REVIEW ARTICLE

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#### ABSTRACT

Although there are many ways to sterilize drinking water such as chemical and physical methods, many countries still use chlorine to sterilize drinking water. Several researches have shown a strong correlation between chlorine used in water sterilization and the emergence of a large number of diseases when it reacts naturally with organic matter found in water such as decaying tree residues and animal material, producing substances known as chlorinated hydrocarbons which has adverse effects on health, so this article review aimed to investigate the influences of chlorine on health in general.

**Keywords**—Chlorine, by-products, disinfection, water, carcinogenic, health effects

#### INTRODUCTION

The problem of water contamination is an unending difficult. Thousands of people were dying because of many disease cholera, typhoid fever and amebic dysentery, during the 20s and 30s which are transmitted through polluted drinking water. When chlorine was used to sterilize drinking water, this was reflecting one of the most crucial progresses in water management in the 20th century. Water chlorination started in 1890 to eliminate the causes of these diseases. Thanks to this discovery, these diseases have been eradicated and humanity has reached remarkable expansions in the value of drinking water and the preservation of the environment. In the current time about 98% of drinking water is sterile by chlorine around the world. Despite the importance of chlorine in the sterilization of drinking water, sewage and industrial waste, drinking chlorinated water and direct exposure to chlorine gas has significant adverse effects. Several studies have confirmed that chlorine is directly related to liver, bladder, intestinal cancers, Arteriosclerosis, high blood pressure and allergies.

**Structure of chlorine and its properties:** Chlorine word means the pale green, it is chemical element has the Atomic number 17 and the symbol (Cl). Chlorine represents a member of halogens where it presents in the group 17 of the periodic table of the elements. It is yellow-green gas in the room temperature, its melting point at  $-101^{\circ}\text{C}$  while the Degree of assimilation is  $-34.6^{\circ}\text{C}$ . It smells irritating and pungent like the smell of bleached detergents. The density of chlorine gas is more than the density of the air as it is dense ( $3.21 \times 10^{-3}\text{g/cm}^3$ ), for this reason chlorine accumulates at points at low levels on the surface of the earth slowly rising into the air, causing an increased exposure time (Sander 1999). Chlorine is characterized by its weak degra-

ation in water. Liquid chlorides, as well as organic solvents, increase chlorine solubility due to chlor-

ine, whether wet or liquid, of high ability to destroy and destroy most of the known metals no matter how different its resistance, such as gold, silver, platinum and tantalum, For wet and dry chlorine (Keil and Shepson, 2006). Chlorine is non-flammable but is associated with other substances involved in the manufacture of explosives. It also lacks power and interacts strongly with many organic compounds (Kercher *et al.*, 2009). The chlorine evaporates rapidly if it is exposed and its viscosity equals one-third of the viscosity of water and its volume in its gaseous state is greater than its liquid state by 450 times. This means that a cubic meter of liquid chlorine can produce about 450 of gas. Chlorine is used in its liquid state (sodium hypochlorite) or solid in powdered form in water sterilization and the chlorine solubility in the water and its interaction lead to the formation of derivative causing biological damage (Baker *et al.*, 2016). These reactions are including:

- 1-  $\text{Cl}_2 + \text{H}_2\text{O} = \text{HCl} + \text{HOCl}$  (Hypochlorous acid).
- 2-  $\text{Cl}_2 + \text{H}_2\text{O} = 2\text{HCl} + [\text{O}^-]$
- 3-  $\text{HOCl} = \text{HCl} + [\text{O}^-]$

**History of chlorine:** The chlorine was discovered by Carl Wilhelm Scheele in 1774 AD, which he thought contained oxygen but was corrected by Sir Humphry Davy, who insisted that he was a chemical element, which he named chlorine in 1810 AD.

In 1810 AD chlorine was first used in water sterilization in limited areas and after obtaining amazing results in eliminating the pathogens of many diseases, it was widely used for sterilizing drinking water in Chicago, USA in 1908 AD (Wisniak, 2002). Chlorine is one of the first toxic gases used as a weapon in wars during the First World War.

On April 22, 1915, in a battle near the Belgian city of Ibery, the German army fired large quantities of this gas into cylinders stored in trenches which led to the retreat of French troops (Fitzgerald, 2008).

**Chlorine sources and its using:** Chlorine is naturally associated with other elements, especially sodium as NaCl, as well as carnallite and sylvite. Chlorine forms many soluble salts in ocean waters. Chloride ions represent 1.9% of the sea water mass. The amount of chlorine in the soil varies depending on the distance from the sea. The chlorine rate in the upper layers of the soil is about 10 ppm. The plants also contain different levels of chlorine, as it is one of the main nutrients of the upper plants. It is concentrated in green plastids (Chen et al., 2010). The human body contains chlorine in the form of chloride and rarely cause deficiency in this element in humans except in cases of vomiting and diarrhea, severe and persistent sweating and waste, where the chlorine enters the synthesis of intestinal acids and participate in the process of digestion of food and share with potassium and sodium in reducing the balance of water and fluids and helps to secure Function of muscles and nervous system (Rolfes et al., 2012).

Chlorine has multiple uses as it is used in the purification of drinking water as a disinfectant and is also used as bleach. Chlorine enters the industry directly or indirectly, which is used in the paper, paints, pesticides, paint, plastics production petro-latium and tissue industry and solvent industry (Sioris and Shuller, 2007). Chlorine is used in the pulp of wood pulp used in the manufacture of paper and helps to remove ink from recycled paper in addition to it is used as an alternative to hydrogen in the industrial rubber industry. It also enters into the manufacture of organic materials such as chlorite, chloroform and carbon tetrachloride, as well as contributes to the extraction of bromine (Perez and Mckay, 2007).

**Methods of exposure to chlorine:** There are many faces for the use of chlorine in the industrial and commercial fields, so exposure to it is accidental by freeing or draining it from storage containers or dealing directly with it in factories and water purification plants. The most harmful methods of exposure are inhalation of chlorine gas or by direct contact with the skin and the eye or through ingestion of food and chlorine-containing water.

**Health damage of chlorine:** The benefits of chlorine use in the sterilization areas are very clear, but despite its usefulness, it has adverse effects. While it was thought to prevent the spread of epidemics, it has been helpful in the development of other diseases. When chlorine is added to sterilize drinking

water, it reacts naturally with organic matter found in water such as decaying tree residues and animal material, producing substances known as chlorinated hydrocarbons, Trihalomethanes which are chloroform, benzene, bromoform, dibromo-chloromethane, bromo-dichloromethane (CIS, 2014). These substances are found in the most common water supply. The EPA in 2014 has classified these compounds as the main causes of cancer, especially liver, kidney and colon cancer, where the concentration of chloroform in drinking water has increased over time as the normal proportions of its presence in water are 2-68ppb.

The exposure to chlorine increases when swimming with chlorinated water as the temperature of the water to 30°C increase the proportion of chloroform to 0.2mg, but if it rose to 40°C, the concentration of up to 7mg, resulting in a lack of blood flow in the capillaries near the skin, To spread across large distances through which it reaches the bloodstream (Michaud et al., 2007). The inhalation of chlorine vapor during bathing increases the problems of asthma, allergies and sinuses. Short-term exposure to these conditions can cause eyes, cough, sputum, chest and nose pain.

Exposure to it further causes fluid accumulation in the lung, pneumonia, bronchitis and dyspnea. It was found that exposure to fumes during shower use was 100 times more frequent than drinking the same water. The body was found to absorb the volatile chemicals during bathing. The effects can be summarized in the body's organs as follows:

**Respiratory system:** It is the occurrence of irritation and inflammation of the nose and throat membranes and inflammation of the respiratory tract, where exposure to a high concentration of chlorine can lead to the accumulation of fluid in the lung and swelling, and lead to bronchitis and can lead to death due to suffocation, Chronic symptoms due to exposure to low levels of chlorine are continuous, especially by workers who work in institutions producing chlorine-containing bleach, drinking water purification and sewage, and they may have symptoms of bronchitis and asthma. They may become more susceptible to Tuberculosis (Patil et al., 2002). Though, chlorine-based sterilizers, which include chlorine, hypochlorite, yet chloroisocyanurates are the nearly frequent water sterilizers because of the obstruction concerning lotus borne illnesses. When disinfectants arouse together with natural amino complexes, sterilization byproducts (DBP's), regularly denoted according to like trihalomethanes, are wrought. Organic compounds, for instance, hypochlorous acid yet chloramines, cause oxidation for muscles, which damage epithelial tissue junctions

and cause rise the permeability of lung epithelium. Frequent exposure over it marketers triggers the improvement about bronchial asthma or potentially permits the passage on allergens. Exposure of chlorination then natural count or decreased ventilation beyond indoor swimming pools may hold hazardous acid and persistent consequences concerning the respiratory law (Nemery et al., 2002; Bernard et al., 2006). Kids, lifesavers, tank attendants, and the best bathers are at an amplified jeopardy because of arising top or decrease respiratory issues (Lourencetti et al., 2008).

Epithelial or mucosal destruction triggered by way of incur in conformity with chlorine products into kids under the age five years, pond followers then competitive swimmers motives a before long onset concerning allergies (Bernard et al., 2006). Kids yet youth are nearly prone according to thriving health consequences due to the fact on the expanding usage in childhood for bodily undertaking (Bougault et al., 2009) or it is tending to stand swimming among water as is hotter and have greater ranks about sterilizer (Weisel et al., 2009). Chlorine tiers are commonly in 1.0 – 3.0ppm among unrestricted swimming pools, each indoors yet outdoors, then is extended upon water than surface pollution. The encouraged chlorine ranges are directed via governance groups in accordance with avoiding recurrent of illnesses because of water (Centers for Disease Control and Prevention, 2010). The study of (Bougault et al., 2012) found that the swimming for a long time in chlorinated swimming pools leads to changes in airways like that happened in asthma with the more expression of mucin.

**Eyes:** The chlorine reaction with the mucous membrane of the cornea is highly acidic, but the proteins present in the tears work to reduce the damage of these acids, which cause burns in the membranes of the corneal epithelium, that can heal with time. Burns that occur in the center of the cornea may lead to an ulcer and then leave a scar inside (Bernard, 2007).

**Skin and hair:** Bathing and ablution with chlorinated water which is cause scalp and skin redness, mainly in people who are most susceptible to allergies. Chlorine is found to be associated with hair proteins, destroying it, causing it dryness and fragile, losing color, it also increases the problems of dandruff. Studies have shown that swimming in the swimming pool with chlorinated water lead to absorption of chlorine by the skin within 10 minutes, which go over eight cups of water of chlorine, making the skin dry and itchy (Cmest, 2002). Swimming in a chlorinated pool can dry out the skin and make it tight and irritated on the grounds that

the chlorine strips the skin of its normal oils. Individuals with delicate skin may even get aggravation or a rash from the pool's drying impacts. Chlorine likewise can worsen skin conditions like dermatitis.

Chlorine really advances the age of free radicals inside the body, and particularly the skin. Free radicals have been appeared to cause malignancy, as has chlorine. Drinking faucet water most has been connected to bladder, breast and bowel cancer and long-term impacts of drinking, washing and swimming in chlorinated water has been appeared to cause dangerous melanoma, also called skin cancer. Chlorinated water to advance the process of aging, like the impacts of stretched out presentation to the sun.

**Teeth:** The continued contact to chlorinated water, whether by drinking water or swimming, can cause tooth decay and weakness. It has been found that workers who work in institutions and factories that use chlorine appear on their teeth to corrode due to hydrochloric acid formed as a result of the chlorine reaction with the moisture in their mouth besides inflammation of the lining of the mouth (Pereira et al., 2006).

In a case report depicts the relatively total loss of enamel by corrosive disintegration, especially from the front teeth, in a lady who swam day by day for about fourteen days in an inappropriately chlorinated swimming pool in Cuba. It accentuates the requirement for the two swimmers and swimming pool team to guarantee that water has been appropriately chlorinated and that the pH has been changed in accordance with 7.5 (Dawes and Boroditsky, 2008).

**Digestive system:** Exposure to chlorine by swallowing and dealing with chlorine-containing detergents at home leads to vomiting and chest pain. Prolonged exposure leads to irritation of the pharynx, esophagus, and liver and intestinal tissue. Several studies found that the drinking of water contain chlorine derivatives (trichloromethanes) such as chloroform is a carcinogenic agent for rats and mice. Inhalation of chlorine can lead to cancer risk (IARC, 2006). There is an increase of 15-35% in cancer among people who use chlorinated water compared with other non-chlorinated water where noticed the presence of correlation between bladder and rectum cancer with consumption of chlorinated water. Several studies indicated the presence of positive correlation between colon, stomach, pancreas, liver, bladder and anal cancer and the exposure to chlorinated byproducts in drinking water (Weiderpass et al., 2003; Slattery et al., 2006; Villanueva et al., 2007).

**Heart:** Chlorine is one of the oxidizing substances that reduce the level of oxygen in the cells, increasing the risk of heart disease. It has been shown that chlorinated water has an effect on the heart and circulation device, which leads to poor circulation and low growth in birds treated with chlorinated water compared to the group that took chlorine free water (Price, 1987).

**Abortion:** Chlorine reacts with a naturally occurring organic matter, during the production of drinking water and lead to the formation of Disinfection by-products (DBPs) which is causes adverse reproductive effect, such as, intrauterine growth retardation, low birth weight and spontaneous abortion (Richardson *et al.*, 2002). In a cross-sectional study carried out by (Nieuwenhuijsen, et al., 2008) indicate an increase in the birth defect such as cleft palate anencephalus and ventricular septal defects risk, from prenatal exposure to disinfection by-products in drinking water (Mohsen et al., 2016).

It is found that women who drink chlorinated water increase their miscarriages and birth of dead fetuses and also increase the number of birth defects that suffer from heart problems, cleft palate and brain abnormalities, where chlorine is one of the important factors that contribute to the increase of breast cancer across the world (Jaakkola, 2007; Barrie, 2009).

### Conclusions

In spite of chlorine importance in the water disinfection and decrease the pathogens in the water, chlorine gas is fatal even if it is at concentrations as low and has important role in the occurrence of several diseases through its participant in the deficiency of immunity, cancer and Abnormalities. The presence of alternatives become important to decrease these effects that has become so widespread, As some countries still use this substance in water sterilization, it is necessary to look for less hazardous and less harmful substances.

### REFERENCES

- Baker, A.K., Sauvage, C., Thorenz, U.R., van Velthoven, P., Oram, D.E., Zahn, A., Bernninkmeijer, C.A.M. and J. Williams, Evidence for strong, widespread chlorine atom chemistry associated with pollution outflow 33 from continental Asia. *Sci. Rep.* 6: 36821 (2016).
- Barrie, Q., The breast cancer epidemic science of the total environment. 217: 155-163 (2009).
- Bernard A., Chlorination products: emerging links with allergic diseases. *Curr. Med. Chem.* 14 (16): 1771-1782 (2007).
- Bernard, A., Carbonnelle, S., de Burbure, C., Michel, O. and M. Nickmilder, Chlorinated pool attendance, atopy, and the risk of asthma during childhood. *Environmental Health Perspectives* 114(10): 1567- 1573 (2006).
- Bougault V., Loubaki L., Joubert P., Turmel J., Couture C., Laviolette M., Chakir J and L.P. Boulet, Airway remodeling and inflammation in competitive swimmers training in indoor chlorinated swimming pools. *J. Allergy Clin. Immunol.* 129: 351-358 (2012).
- Bougault, V., Turmel, J., Levesque, B. and L.P. Boulet, The respiratory health of swimmers. *Sports Medicine* 39(4): 295-312 (2009).
- Centers for Disease Control and Prevention. Violations identified from routine swimming pool inspections—selected states and counties, United States, 2008. *Morbidity and Mortality Weekly Report* 59(19): 582-587 (2010).
- Chen, W., Xiao, Z.L., Yang, H.E., Mishra, S. and P.J. Stoffella, Chlorine nutrition of higher plants: progress and perspectives. *Journal of Plant Nutrition* 33(7): 943-952 (2010).
- Cmest, H., The public health consequences from swimming pool chlorinator tablets. *J. occup. Environ. Med.* 44(10): 906-13 (2000).
- Dawes C. and C.L. Boroditsky, Rapid and severe tooth erosion from swimming in an improperly chlorinated pool: case report. *J. Can. Dent. Assoc.* 74(4): 359-361 (2008).
- Fitzgerald, G.J., Chemical Warfare and Medical Response During World War I. *Am J Public Health.* 98(4): 611-625 (2008).
- International Agency for Research on Cancer. Working Group on the Evaluation of Carcinogenic Risks to Humans, Some Chemicals that Cause Tumours of the Kidney or Urinary Bladder in Rodents and Some Other Substances. *IARC Monographs on the Evaluation of Carcinogenic Risks to Humans*, ed. IARC. Lyon, France: IARC. Vol. 73 (2006).
- International Occupational Safety and Health Information Centre (CIS), Chlorine, in *International Chemical Safety Cards*, 31 March 2009, International Programme on Chemical Safety (IPCS) and European Commission (EC), Accessed 24th July (2014).
- Jaakkola, C., Chlorine in tap water, nearly double the risk of birth defect. *New York, Elseviere* Pp. 74-86 (2007).
- Keil, A. and P. Shepson, Chlorine and bromine atom ratios in the springtime Arctic troposphere as determined 39 from measurements of halogenated volatile organic compounds, *J. Geophys. Res.* Pp. 111 (2006).
- Kercher, J.P., Riedel, T.P. and J. Thornton, A Chlorine activation by N2O5: simultaneous, in situ detection of 41 ClNO2 and N2O5 by chemical

- ionization mass spectrometry, *Atmos. Meas. Tech.* 2: 193–204 (2009), doi: 10.5194/amt42-193-2009
- Lourencetti, C., Fernández, P., Marco, E., Ballesté, C., Grimalt, J. O., Font, L. and M. Kogevinas, Trihalomethane levels in exhaled breath as indicators of exposure to disinfection by-products in indoor swimming pools using chlorine and bromine as disinfectants. *Epidemiology* 19(6): 191–192 (2008).
- Michaud D.S., Kogevinas M., Cantor K.P. et al., Total fluid and water consumption and the joint effect of exposure to disinfection by-products on risk of bladder cancer. *Environmental Health Perspectives* 115(11): 1569–1572 (2007).
- Mohsen, I.H., Zaidan, H.K. and A. Al-Saadi, Estimation of sex hormones in type 2 diabetes patients. *International J. of Chem. Tech. Research.* 9(6): 476–487 (2016)
- Nemery, B., Hoet, P.H. and D. Nowak, Indoor swimming pools, water chlorination and respiratory health. *European Respiratory Journal* 19 (5): 790–793 (2002)..
- Nieuwenhuijsen, M.J., M.B. Toledano, J. Bennett, N. Best, P. Hambly, C. de Hoogh, D. Wellesley, P.A. Boyd, L. Abramsky, N. Dattani, J. Fawell, D. Briggs, L. Jarup and P. Elliott, Chlorination disinfection by-products and risk of congenital anomalies in England and Wales. *Environ Health Perspect* 16: 216–222 (2008).
- Patil L.R., Smith, G., Vorwald, A.J. and T. Mooney, The health of diaphragm cell workers exposed to chlorine. *Am. Ind. Hyg. A Ssoc J.* 31(6): 678–86 (2002).
- Pereira, W.E., Hoyano, Summons, R., Bacon, V. and A. Duffield, Chlorination studies, the reaction of aqueous hypochloric acid with alpha amino acids and peptides. *Biochim. Biophys. Acta* 313(1): 170–80 (2006).
- Perez, A. and C. McKay, Halogens (bromine, iodine and chlorine). Haddad and Wichester's clinical management of poisoning and drug, 4<sup>th</sup> ed. Philadelphia, pa. saunder Elsevier; chap. 96.
- Price, J., Coronaries/Cholesterol/Chlorine, Revised edition Pp. 13 (1987).
- Richardson, S.D., Simmons, J.E. and G. Rice, Disinfection byproducts: the next generation. *Environ. Sci. Technol.* 36: 198–202 (2002).
- Rolfes, S.R., Pinna, K. and E. Whitney, Understanding Normal and Clinical Nutrition. Book 9<sup>th</sup> edition, chapter 12 page 398 (2012).
- Sander, R., Modeling atmospheric chemistry: Interactions between gas-phase species and liquid cloud/aerosol 24 particles. *Surv. Geophys.* 20: 1–31 (1999).
- Sioris, L.J. and H.K. Shuller, Soap, detergents and bleaches. Haddad and Wichester's clinical management of poisoning and drug 4<sup>th</sup> ed. Philadelphia, pa. saunder Elsevier; chap 102 (2007).
- Slattery, M.L., C. Sweeney, M. Murtaugh, K.N. Ma, B.J. Caan, J.D. Potter and R. Wolff, Associations between vitamin D, vitamin D receptor gene and the androgen receptor gene with colon and rectal cancer. *Int. J. Cancer* 118(12): 3140–3146 (2006).
- United States Environmental Protection Agency (EPA). Basic Information about Disinfection Byproducts in Drinking Water: Total Trihalomethanes, Haloacetic Acids, Bromate and Chlorite. 13 December 2013. Accessed on 23th July (2014).
- Villanueva C.M., Cantor C.P., Grimalt J.O. et al., Bladder cancer and exposure to water disinfection by-products through ingestion, bathing, showering, and swimming in pools. *American J. Epidemiology* 165(2): 148–156 (2007).
- Weiderpass, E., H. Vainio, T. Kauppinen, K. Vasama-Neuvonen, T. Partanen and E. Pukkala, Occupational exposures and gastrointestinal cancers among Finnish women. *J. Occup. Environ. Med.* 45(3): 305–315 (2003).
- Weisel, C.P., Richardson, S.D., Nemery, B., Aggazzotti, G., Baraldi, E., Blatchley, E.R., III, and S. Sattar, Childhood asthma and environmental exposures at swimming pools: State of the science and research recommendations. *Environmental Health Perspectives* 117(4): 500–507 (2009).
- Wisniak, J., The History of Chlorine-From Discovery to Commodity. *Indian Journal of Chemical Technology* 9(5):450–463 (2002).