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ANALYSIS OF MODERN SAFE METHODS OF DRINKING WATER DISINFECTION

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Abstracts

This paper considers the alternative methods of drinking water disinfection and their benefits, which can be offered for drinking water treatment. Such methods are the usage of chlorine dioxide or oxidants mixtures. Their main advantages are much fewer or no formation of toxic and carcinogenic by-products (trihalomethanes and haloacetic acids), removal of biofilms from water supply pipes, stronger disinfectant properties and availability, and safety of necessary substances.

Key words: *disinfection, organochlorine compounds, chlorine dioxide, oxidants, biofilm.*

Introduction

Since water is the factor without which human life is impossible, its high quality must be a priority of every state. This is especially true for quality by sanitary-hygienic indicators, which are provided by disinfection. The deviation from limit values of such indicators can cause serious outbreaks of infectious and intestinal diseases. However, one may not ignore the sanitary-chemical indicators, which can also have a negative impact on human health.

There are many methods of drinking water disinfection, but a lot of them have great disadvantages. For example, the usage of chlorine, sodium hypochlorite or chloramine is accompanied by the formation of toxic and carcinogenic by-products – organochlorine compounds. Ozonation requires extremely high investment and is accompanied by the formation of mutagenic and toxic products as well. Ultraviolet is ineffective against some viruses. Besides, ozonation, ultraviolet light and ultrasound do not provide aftereffect. This may result in recontamination during the water supplying to the consumer. The usage of silver can cause its accumulation in the human body and some diseases as heavy metal. Moreover, it is proved that the silver ions do not affect on spore-forming bacteria. Thus, such alternative methods of drinking water disinfection as the usage of chlorine dioxide or oxidants mixtures (Bahir 2003, Kramarenko 2010, Styskal and Petruk 2014, Styskal and Petruk 2013) recently started to be implemented in the world. Consequently, their thorough analysis is the aim of this study.

Alternative methods of drinking water disinfection

The disinfection by oxidants mixture (HClO, OCl^-, Cl_2)

1. The method is patented by MIOX Company (USA) (David Von Broembsen 2012). Oxidants mixture is produced by electrolysis of sodium chloride solution. The safe

products usage (water, salt) allows to avoid keeping dangerous chemicals such as liquid chlorine or sodium hypochlorite, that require a special arrangement of security zones and in the case of leak can cause environmental catastrophe (Shubenok 2014).

Production of oxidants mixture at the place of consumption helps to eliminate the necessity of hazardous substances transportation. This results in reduction of transport cost and costs for providing the safety of transportation (Shubenok 2014).

Oxidants mixture effectively removes biofilms and does not allow further its forming in water storage tanks and pipelines (fig. 1). Existing biofilms absorb residual chlorine in water, give to water an unpleasant taste. This cause the necessity of increasing of chlorine initial dosage to achieve desired concentration in the final place of consumption. Increasing the initial dose of chlorine causes the formation of dangerous carcinogenic compounds. Removing the biofilms with help of oxidants mixture is the way for significant reducing the amount of chlorine dosage. This guarantees the improving of organoleptic properties of water and reduces the formation of disinfection by-products (Shubenok 2014).

a) b) c)

Figure 1. The inner surface of the water supply pipe (David Von Broembsen 2012): a) using hypochlorite; b) after 6 days usage of oxidants mixture; c) after 22 days usage of oxidants mixture.

Oxidants mixture has stronger disinfecting properties in comparison with hypochlorite or liquid chlorine. Compared to chlorine, oxidants mixture of the same amount and during the same time provides more thorough and rapid removal of a larger number of microorganisms and has better taste and odor characteristics. At equal doses the content of residual chlorine after usage of oxidants mixture is significantly higher than after hypochlorite or liquid chlorine usage (Shubenok 2014). In the case of oxidants mixture using the level of residual chlorine is constant in the entire length of water supply pipe for a long time. This effect is closely associated with the removal of biofilm which tends to consume residual disinfectant in the water supply system. This significantly reduces oxidative needs (sayt ONIKO).

Low concentration of chlorine in the solution of mixed oxidants (less than 0.5 %) prevents corrosion of water supply pipes that can significantly extend their operation time. The concentrations of chlorine vapors in the air in work areas are as follows: sodium hypochlorite using – 0.03 mg/m^3, oxidants mixture using – 0.0095 mg/m^3 (sayt kompaniyi ONIKO).

Investigations of oxidants mixtures storage indicate on very low degradation disinfectant level that allows oxidant mixture solution to keep the performance up to 20 times longer comparing with sodium hypochlorite (Sayt ONIKO).

One of the stages of water treatment is microflocculation. The usage of oxidants mixture solution at the stage of pre-treatment reduces water turbidity and coagulant consumption up to 40%. In addition, there is more rapid formation and dropping out of flakes and reducing the formation of disinfection by-products due to the reduction of the organic matter amount (Sayt ONIKO). Such oxidants mixtures have the ability to neutralize components which cause odor (Sayt ONIKO).

Most importantly, the using of oxidants mixture reduces the formation trihalomethanes and haloacetic acids due to the following factors:

1. A stronger disinfectant action of oxidants mixture ensures removal of biofilms from the water supply system and thus reduces the level of organic matter and, as a result, the following reduction of water oxidation.

2. Due to low water oxidation, the dose of chlorine is decreased and thus the limit of residual chlorine level is guaranteed.

3. The usage of oxidants mixture for water treatment stage, including pre-treatment, under certain conditions, provides effect of microflocculation when organic compounds are removed from the water, this later results in reducing the number of trihalomethanes.

Reducing the number of trihalomethanes is confirmed by numerous studies with oxidants mixture (fig. 2) (Sayt ONIKO). Reduction typically ranges from 20% to 50%. Similarly, there is reduction of haloacetic acid (Sayt ONIKO).

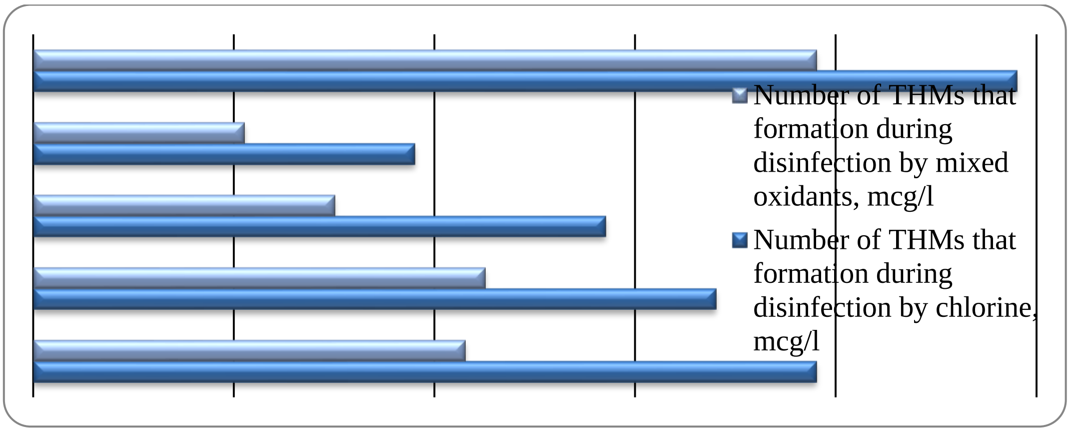

Figure 2. Characteristics of the trihalomethanes (THMs) formation during the chlorination and disinfection by oxidants mixture (Sayt ONIKO).

There is known another oxidants mixture (HClO, Cl_2, O_3, H_2O_2, ClO_2), which is able to remove biofilm from a surface of water supply pipes and does not have any harmful effects on humans and environment (fig. 3). It is connected with the principles of water treatment technologies that are based on the usage of mechanism for water disinfection created by nature to protect human and animal from infections. All higher multicellular organisms, including humans, synthesize hypochlorous acid and highly active metastable chlorine-oxygen and hydroperoxide compounds (metastable mixture of oxidants) in specific cellular structures (microsomes of hepatocytes, endoplasmic reticulum of phagocytes) to fight with pathogens and foreign substances. This antibacterial protection mechanism, created by nature, operates in the internal environment of animals and humans within millions years without any glitches. Exactly similarity of this processes provides the harmlessness of oxidants mixture to the human body and the microorganisms disability to adapt to the metastable oxidants mixture (Grishkov et all.).

These oxidants together with hydroperoxide oxidants which are located in microdrops of moisture, provide a powerful synergistic oxidative effect on organic compounds in water, effectively preventing the formation of trihalomethanes and other organochlorine compounds. Also oxidants solution in contrast to traditional chlorinated water effectively removes biofilm from inner surface of water supply pipes. This reduces the pipes corrosion, provides an excellent organoleptic properties of water (Grishkov et all.).

The advantages of this method are next: creation of systems of any productivity in the workplace of different configurations; there are not required any project, special construction or installation works; safe operation; fundamentally new process of electrochemical decomposition of saline; automatic reagent-free cleaning of electrochemical reactors; automatic maintenance of a preset concentration of oxidants in disinfected water (Bahir 2003, Sayt Delfin Aqua).

Today such technology is used on the water treatment stations in USA, Germany, Finland, Georgia, Turkey, Ukraine, Kazakhstan, Malaysia, Ecuador, Spain and other countries (Ofitsiynyy sayt kompaniyi Delfin Aqua).

***Drinking water disinfection by chlorine dioxide** (ClO_2)*

The ways which significantly reduce or practically eliminate the trihalomethanes (THMs) formation are the removal from water the substances, from which trihalomethanes are formed, on the stages of water preparation to chlorination (these methods are well known and widely used), and the usage of oxidants which react with organic compounds differently than chlorine or bromine. For example, the mechanism of interaction of chlorine dioxide with humic and fulvic acids is fundamentally different from the mechanism of interaction of chlorine with these compounds. Chlorine dioxide acts as oxidant, while during the treatment of water by chlorine takes place oxidation and electrophilic replacement (chlorination), which leads to the THMs formation. Numerous studies have shown that chlorine dioxide, reacting with substances, which are sources of THMs, deactivates them and makes them unable to react for trihalomethanes formation. This means that pre-treatment of water with chlorine dioxide inhibits the trihalomethanes formation, even if at a later stage water treatment by chlorine is used. However, even the combination of chlorine with chlorine dioxide is not always effective for biofilms removal (Kramarenko 2010, Grishkov et all.). Besides, this disinfection method not requires the transportation and storage of flammable materials (because chlorine dioxide is used at the place of its obtaining) and is accompanied by the formation of chlorates and chlorites (Bahir) 2003). However, the data obtained by authors (Mokienko 2008) indicate on chemical harmless of drinking water disinfected by chlorine dioxide.

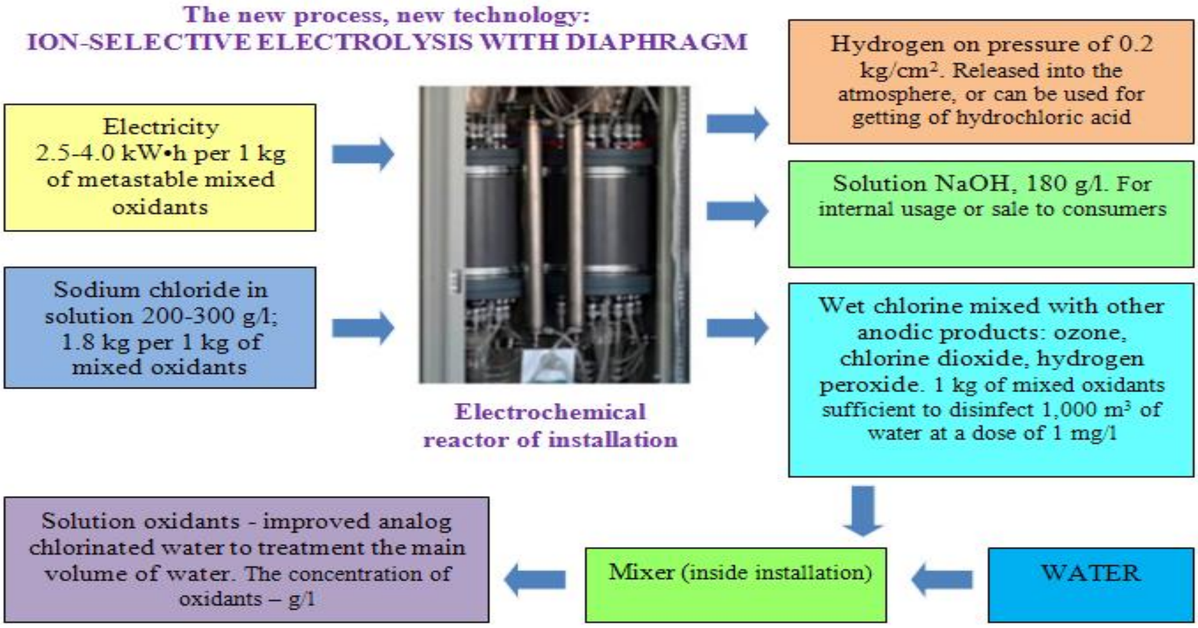

Figure 3. Scheme of the technological process with oxidants mixture usage (Grishkov et all.).

Chlorine dioxide is unstable gas that can be produced at the place of usage in the form of water solution from hydrochloric acid solution and sodium chlorite ($NaClO_2$) by the following reaction (Ofitsiynyy sayt EKVENT):

$$5NaClO_2 + 4HCl = 4ClO_2 + 5NaCl + 2H_2O$$

Chlorine dioxide by strength of disinfectant action exceeds chlorine 4 times and actually has no negative consequences due to a special chemical mechanism of action on contaminants and microorganisms. Chlorine dioxide has the following advantages: - does not form trihalomethanes (THMs) and chlorophenols; - actually does not form organic halogens that are not removable; - there is no reaction with ammonia and other nitrogen compounds; - strong disinfecting action practically does not depend on the values of water pH; - strong effect on spores, viruses and algae; - does not make negative changes to the smell, taste and color of water; - oxidizes organic compounds of iron and manganese; - improves the flocculation of untreated water; - independence of redox potential on the pH and on the presence of ammonia and other nitrogen compounds in water; - reduces water hardness; - long-term (7 days) bactericidal effect in water supply systems and, consequently, the removal of microbiological deposits in the system of water pipes (Sayt EKVENT). One of the first water supply systems, which successfully used chlorine dioxide, has been introduced in the US in 1944. In 1958 already 150 of the US water supply systems used chlorine dioxide. In Germany it is used from 1959. Such technology also is used at some cities in Ukraine since 1995 (Sayt EKVENT).

Conclusions

Such alternative methods of drinking water disinfection as the usage of chlorine dioxide or oxidants mixtures can be recommended for the safe water treatment. Their main advantages are much fewer or no formation of toxic and carcinogenic by-products (trihalomethanes and haloacetic acids), removal of biofilms from water supply pipes, stronger disinfectant properties and availability, and safety of necessary substances (salt for oxidants mixture producing, and sodium chlorite and hydrochloric acid for chlorine dioxide producing). However, before usage of chlorine dioxide one should research the methods of by-products extracting (chlorates and chlorites) from drinking water.

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Znezarazhennya vody dioksydom khloru. Ofitsiynyy sayt proektno-montazhnoho pidpryyemstva EKVENT

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