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CONSIDERATION OF THE POSSIBILITY OF USING OZONE IN THE TREATMENT OF DRINKING WATER IN THE "TILAVA" WATER SUPPLY SYSTEM

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ABSTRACT:
In Bosnia and Herzegovina and in the countries in the region, chlorine and its compounds are mainly used as a disinfectant in the process of purifying drinking water. It is a well-known fact that the reaction of chlorine and organic matter in water creates carcinogenic compounds, trihalomethanes, which can negatively affect the health of the population if they are consumed for many years. Therefore, it is necessary to look for an alternative for chlorine. This paper discusses the possibility of using ozone in the treatment of drinking water in the "Tilava" water supply system.

Keywords: *Ozone, Water purification, Water quality, Water supply system "Tilava".*

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1. INTRODUCTION

One of the key problems mankind faces today is supplying population with potable water. It is widely acknowledged that potable water is one of preconditions of good health. Quality of drinking water depends primarilly on potability at sources, which is deteriorated year by year through unplanned tree cutting, building garbage dumps, roads, households and farms in zones around sources. Raw water usually contains impurities such as particulate matter, solutions and microorganisms making it low-quality and unsuitable for immediate consumption. Due to reasons mentioned above raw water must be processed in order to remove contaminants and reach proper quality for supplying. Water quality is determined by examining its physical, chemical and biological properties. In Republika Srpska, potability of water for public supply is surveilled by sanitary inspections and public health institutions in compliance with requests specified in Ordinance on drinking water health quality for human use (Official Gazette of Republika Srpska, No.88/17).

The key task of water-supply companies is to provide their consumers with adequate amounts of drinking water of requested, ie.prescribed quality at all times. In this process, they are faced with problems at sources and distribution systems (asbestos-cement pipe, cast iron pipe etc.). The usual filtration method used in processing of drinking water is conventional procedure and comprises the following: coagulation, flocculation, sedimentation, filtration and disinfection (by chlorine). Ozone has been used lately for drinking water disinfection. This paper discusses possibility of application of ozone in water disinfection at Tilava Water Supply System (East Sarajevo).

2. APPLICATION OF OZONE IN DRINKING WATER TREATMENT

In his work, Skejovic suggests that traditional physical and chemical treatment methods such as flocculation, filtration and chlorination are becoming less efficient because they cannot provide the necessary drinking water quality. This author regards ozone as one of the most efficient purifiers, making it ideal for reaching necessary requirements regarding drinking water quality [1]. Raknes claims that ozone has been used for drinking water treatment for almost 100 years. It was used for the first time in Nice, France in 1906 and was afterwards applied in water purification facilities worldwide. In United States of America, ozone was used for the first time in 1908, and now it is used in drinking water treatment in over 300 facilities [2]. Based on conducted researches it was determined that ozone is applied in Serbia in facilities for treatment of drinking water in Belgrade, Pančevo, Zaječar, Kruševac, Arilje, Kragujevac, Leskovac, Obrenovac, Ub and Aranđelovac. There are no facilities using ozone in technological process of treating drinking water in Bosnia and Herzegovina.

Ozone has high oxidative capacity, due to the fact that its third atome, so-called “instable atome” has a strong tendency to separate and attach itself to other substances, which turns ozone molecule into the shape of oxygen. Ozone can react directly with compound or produce hydroxile radicals reacting with compound [3,4]. During process of drinking water purification, ozone can be added at multiple locations in technological procedure depending on quality of raw water and desired effect. There are following stages of ozone application in the very process [3,5]: pre-ozonation, intermediate ozonation (ozonation during process), post-ozonation.

Figure 1 illustrates stages of ozone application in the process of drinking water purification. In order to acquire maximum efficiency of ozone application in treatment of drinking water, the total amount of ozone must be distributed and applied prior to flocculation (pre-ozonation) and after sedimentation (intermediate ozonation). It is also necessary to avoid feeding large amounts of ozone at the end of the purifying process in order to prevent by-products which could harm consumer’s health.

Pre-ozonation is done by feeding a small amount of ozone prior to flocculation process, most often using excess of ozone from intermediate ozonation, which could otherwise be cathalitically or thermically disintegrated before being released into atmosphere. Application of pre-ozonation decreases the necessary dosage of coagulant by 10 to 30% because ozone decomposes organic part of colloid and turns it into dissolved shape. If the water contains complexes binding organic compounds with iron and manganese, ozone might start coagulation process by its deconstruction.

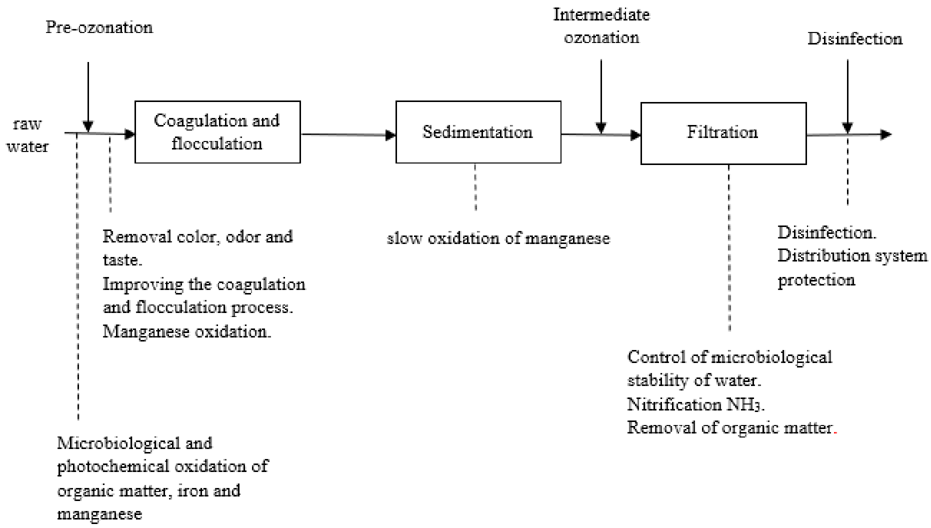

Fig.1. Locations of ozone application in water clarification process [6]

Pre-onization affects precursors of creating trihalomethane (THM) in water clarification process. Ozone creates biodegradable supstances from non-biodegradable ones, thus enabling large quantities of organic matters to be removed from filters, and reduce the necessary dosage of ozone during intermediate ozonation. Ozone dosages in pre-onization range from 0,5 to 1mg/l to maximum 1,5 mg/l depending on characteristics of water, but the amount of residual ozone must not exceed 01, mg/l. Minimum contact time with water should be approximately 2 minutes. High dosages of ozone prior to flocculation may cause negative effects, such as solubility of organic compounds, conversion of manganese to permanganates, etc.

Intermediate ozonization is applied after clarification phase or following filtration. It involves oxidation of large number of inorganic (sulfides, nitrites, chlorides etc.) and organic compunds (phenols, detergents, pesticides, pollycyclic hydrocarbons etc.) as well as disinfection of water in case there is no post-ozonation (removal of bacteria, viruses and spores). Applying ozone in front of two-layer filters enhances their efficiency, and if there is secondary flocculation in front of filters their lifetime will be longer, due to effect similar to that in pre-ozonation phase. If filters with granulated active carbon are applied after two-layer filters, rest of organic components are removed by water adsorption and further biodegradation. However, if there are larger quantities of particulate matter in water after sedimentation, intermediate ozonation must be applied after two-layer filters.

Post-ozonation in preparation of drinking water is mostly used to remove vegetative bacteria (Cryptosporidium ociste, etc.), oxidation of organic supstances, etc. [3].

By applying ozone in drinking water purification water can be disinfected, taste and odour eliminated, water colour removed, organic and inorganic matter oxidated, coagulation improved, turbidity removed, viruses deactivated, algae removed, as well as chlorine-resistant organisms, etc. [2,3,7]. Table 4.2. indicates ozone dosages depending on outcomes of its application.

Table 1. Ozone dosages based on application [3]

No.	Application	Ozone dosage, mg/l
1.	primary disinfection	$0,5 \div 2,0$
2.	eliminating taste and odour	$1,5 \div 2,5$
3.	removing colour	$1,5 \div 4,0$
4.	removing iron and manganese	$0,5 \div 4,0$
5.	organic component oxidation	$1,0 \div 8,0$

There are different tehnical solutions to add ozone to drinking water. Ozone mixes with drinking water in multiple ways, most commonly by: barbotage pipelines, injectors and turbine mixers [2,3].

3. PROPOSAL TO APPLY OZONE IN “TILAVA” WATER PURIFICATION PLANT

"Tilava" water source is a typical karstic spring with huge variations in flow and quality of water, with capacity of 90 to 200l/s. Water source "Tilava" comprises two springs, “Big spring” and “Small spring”, separated by 35-50m [8]. In order to describe current state of the very source and water purification plant "Tilava", literature obtained from "Waterworks and sewerage" utility company of East Sarajevo was used.

Results of analysis of sampled water during research conducted by joint-stock utility company "Waterworks and Sewerage" East Sarajevo indicate that water from the source does not have microbiological and physically-chemical quality due to increased turbidity and that water must be treated before it is distributed to residents. "Tilava" water purification plant is conventional, and process is based on use of chlorine (Figure 2).

As figure 2 indicates, basic phases of water purification in "Tilava" waterworks are: coagulation, flocculation and sedimentation, filtration and disinfection by chlorine. It can be concluded that technology used for treatment in this plant is outdated and not fully acceptible in terms of environment protection. It is necessary to take certain steps to modernise technological process of drinking water treatment at "Tilava" plant.

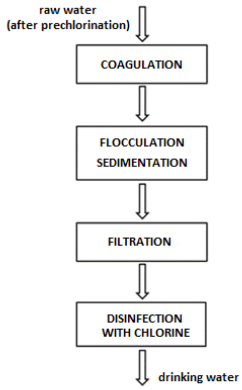

Fig. 2. Technological phases in "Tilava" water purification plant

Analysis of current process of drinking water treatment at "Tilava" was conducted, with special reference to possibility of ozone application. Figure 3 indicates proposal of water purification process in this plant with locations of ozone application in the very process.

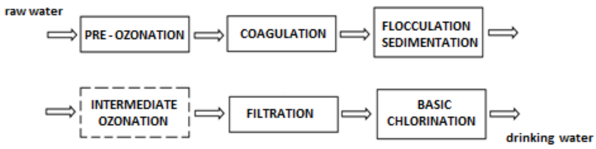

Fig. 3. Proposal of water purification process in "Tilava" water purification plant by ozone application

The modern technological process of drinking water purification would consist of the following phases: pre-ozonation, coagulation, flocculation and deposition, main ozonation, filtration and basic chlorination.

Pre-ozonation. During civil war in Bosnia and Herzegovina from 1992 to 1995 and in post-war period, part of households located between source and drinking water treatment plant was connected to main transport line with a diameter of Ø500. Consequently raw water must be treated before the very plant, so that part of the population has access to potable water, i.e. water which is not carrier of infectious diseases. Ozone is one of the most efficient disinfectants, suitable for inactivitation of viruses and bacteria.

Currently, raw water is pre-chlorinated at the very source to stop the growth of algae. Ozone also stops the growth of algae and prevents biological sludge to appear on the surface, so that pre-ozonation could replace pre-chlorination.Pre-ozonation can successfully regulate the organoleptic quality of water (odour, taste, colour).

Based on available literary data and composition of the water at the source, it was concluded that ozone dose of 1mg/l is sufficient for successful pre-ozonation. This amount of ozone is sufficient to oxidize metal ions in raw water, to stop development of algae, oxidize organic matter and disinfect water.

It is necessary to underline that current process of pre-chlorination takes place in a way that water from the source is transported into a tank with a volume of 5 m^3 by means of a pump and than returned to the raw water tank by free fall. Chlorine is added and water chlorinated along the way. Pre-ozonation would avoid transport of water by pumps and adding chlorine, therefore reducing harmful effects on the environment. Risks related to environment at the source would be reduced to minimum.

Coagulation. Following pre-ozonation, coagulation takes place, that is, mixing coagulants with raw water in order to accelerate sedimentation of suspended particles. If used before coagulation, which is case in this process, ozone decreases the total number of particles in colloid shape by decomposing organic part of colloid and turning it into dissolved form. In this way, ozone facilitites coagulation process and reduces the necessary dosage of coagulants at some plants up to 50%. Another positive effect of pre-onization on coagulation process is reflected in oxidation of metal ions into insoluble complexes.

At the "Tilava" water treatment plant aluminium-sulphate is used as coagulant, whose average consumption is about 20t annually. Bearing in mind that by process of pre-ozonation coagulant consumption is reduced by 30% it is clear that average annual consumption of aluminium sulphate will be reduced to 14 t. This in turn will reduce dosage of solution (aluminium sulphate and water), resulting in reduction of the total amount of dissolved solid particles in water.

Floculation and sedimentation. Flocculation process would be performed at existing four horizontal flocculators with horizontal mixers in order to form larger floccules. It must be highlighted that ozone facilitates flocculation of organic colloid components. Sedimentation of floccules would take place in existing sedimentation tank, whose total volume meets current water demand. Pre-ozonation process will increase efficiency of clarification process, i.e. removal of suspended particles and turbidity reduction.

Intermediate ozonation. Current quality of raw water at “Tilava” water source is such that pre-ozonation with other phases of purification (coagulation, flocculation, sedimentation, filtration, chlorination) would provide potable water. However, if at some point in the future the quantity of metal (manganese, iron) as well as nitrite increases in raw water above the permitted levels, intermediate ozonation must be performed at the water treatment plant. In recent past, there was discussion about exploitation of mineral wealth in water protection zone. That request was rejected, which does not guarantee that such an idea will be discussed again, or even approved. Intermediate ozonation in water purification process is conditional, and it would take place after clarification phase, and before the filtration phase on two-layer filters. The process of intermediate ozonation would increase biodegradability, additional removal of THM precursors and oxidation of metals in water.

Ozone dosage required in the process of intermediate ozonation will be determined based on increased values of manganese and nitrite content above the limit values prescribed by legal regulations. If the values of manganese and nitrite are increased three times more than the permitted limit levels, their oxidation will require approximately 1,7 mg/l of ozone, because oxidation of 1mg/l of manganese takes 0,88 mg/l of ozone, whereas oxidation of 1mg/l of nitrite requires 1,04 mg/l of ozone.

Filtration at the ”Tilava” water purification plant is currently taking place at six square fast gravitation filters, with single-layer sand filling. Following the last replacement of the filtrates the efficiency of the filters was reduced by 20 l/s, i.e. from 180 l/s to 160 l/s of filtered water.

It is proposed to replace single-layer sand filling with two-layer one, where Hydro-Antrahcite and quarz sand would be used as filter material. In this case, impurities penetrate greater depth, and bottom layer of filling which is less porous serves as safety layer to retain particles which might pass through the upper, less porous layer. In this way, filtration will be faster, and these filters might be efficient in case that large quantites of water are required to supply population. Another advantage of two-layer filters is longer period of time between two washes, which in turn enables larger quantities of drinking water to be filtered.

Pre-ozonation is efficient in terms of filtration process; it also accelerates sedimentation of flocs formed and extends filter operation time. Ozone also has effect on organic supstances by decomposing large molecules and creating biodigredable supstances from non-biodigredable ones, therefore increasing filtration rate.

Basic chlorination. Following filtration, water is stored in existing tank with 600 m^3 capacity below filter fields. It is proposed to increase volume of this tank to 1 500 $m^{3,}$ i.e. to increase the reserves of drinking water. In this way, in case of certain intervention on the system (repair, etc), residents would be supplied with water approximately 3 hours smoothly.

Ozone is one of the most efficient disinfectants, however due to its short retention time in water (it can not have residual effect within distribution system [4]) and outdated distribution network at the area covered by Waterworks and Sewerage utility company of East Sarajevo, there is possibility for microorganisms to be developed in the distribution network. Due to above mentioned reasons, ozone disinfection must be combined with alternative secondary disinfectant. Thus, final disinfection with small amounts of gas chlorine is reccomended. It is necessary to control the residual effect of chlorine of 0,2 mg/l.

Although chlorine is used at the end of drinking water purification process, the possibility of trihalometane formation is reduced because ozone prevents its first fractions, i.e. pre-ozonation affects precursors (organic matter) of THM formation. By removing precursors, necessary amount of chlorine for water disinfection at the end of drinking water purification process is reduced.

4. CONCLUSION

Results of conducted researches indicate that chlorine successfully disinfects water, and there are some problems due to formation of certain side effects, primarily trihalometane. These cancerogenic compounds are formed during chloration of natural organic matter present in water. Therefore chlorine is not appropriate for use in drinking water purification. Alternative and ecologically acceptable disinfectant should be used instead. Application of ozone in drinking water purification produces extraordinary results in terms of ecology. Advantages of ozone application comprise its ability to disinfect water at a lower concentration and in shorter contact time as compared to chlorine and its compounds.

This paper discusses possibility of application of ozone instead of chlorine in treatment of drinking water at “Tilava” plant. The procedure of drinking water purification by ozone application at this plant is presented. Instead of pre-chlorination of water at the source pre-ozonation of water would take place, which would achieve required technological and ecological effect.

Conducted researches demonstrated that current quality of raw water at „Tilava“ source is such that pre-ozonation combined with purification phases that are implemented would provide potable water. In case of increase in metal (manganese, iron) and nitrite in raw water above permitted levels in the forthcoming period, intermediate ozonation must be performed at the water treatment plant.

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