УДК 628.162

V. I. Ramanouski[1], V. V. Likhavitski[1], M. V. Rymovskaia[1], A. D. Hurynovich[2]
[1]Belarusian State Technological University
[2]Belarusian National Technical University

DETERMINATION OF THE MAIN PARAMETERS OF DISINFECTION OF DRINKING WATER SUPPLY FACILITIES BY OZONE

This paper analyzes the existing techniques of disinfection of water wells and drinking water facilities using chlorine-containing disinfectants. The advantages and disadvantages of the promising methods of disinfection by ozone using have been described in the paper.

To achieve this goal the recommended values of such parameters as the processing time, the concentration of ozone in the gas mixture, flow rate of ozone, gas mixture flow have been determined. Such values of the investigated parameters in the water treatment as the concentration of ozone in the gas mixture (35, 45, 55 g/m^3) and the processing time (15, 30, 45, 60 min) have also been determined.

The selection of recommended processing parameters, such factors as the results of studies of the kinetics of ozone water saturation, determination of residual ozone in the water from the incoming in system, the dynamics of ozone decomposition in water, as well as the time required to achieve 100% inactivation of the studied strains of bacteria, the dependence residual ozone concentration of ozone in the gas mixture, the gas mixture flow have been taken into account. To determine the optimal parameters of disinfection depending on the treatment parameters, the regularities presented in the form of equations have been established.

The recommended settings to select an ozone generator have been suggested on the basis of these results for proposed scheme of disinfection.

Key words: disinfection, ozone, water treatment, construction, parameter, processing.

Introduction. Water disinfection is used for its purification from pathogens and other microorganisms and viruses as water becomes unfit to drink, housekeeping or industrial needs. Thus, disinfection of utility network and constructions is one of the method of disinfection and includes a number of measures aimed at eradication of agents of infection and destroying of toxins on the surface of using systems.

According to currently effective regulatory documents, in the Republic of Belarus disinfection of well shafts, clean-water reservoirs and potable water supply pipelines is carried out with chlorine substances. Thus, in reality, calcium hypochlorite and sodium hypochlorite are preferred, rarely liquid chlorine and new chlorine-containing solutions are used.

Yearly average in the Republic of Belarus about 20 t of calcium hypochlorite, 30 m^3 of sodium hypochlorite and 0.5 t of chlorine-containing solution "Aquatabs" are used.

Besides chlorine-containing decontaminating materials, ozone is recently widely practiced during water treatment [1–4]. In Table 1 there are the results of the analysis of different methods of disinfection and decontamination used in different countries [5].

Techniques of ozone usage for disinfection of water-supply wells and potable water systems instead of currently used chlorine-containing reagents are proposed by the authors [6, 7]. Commercial ozone generators are distinguished by the presence of feed gas and pure oxygen in balloons or air can be used as the source of this feed gas. Commercial ozone generators are also distinguished by concentration of ozone in gas mixture and flow volume of gas mixture.

The aim of this paper is to find out key parameters of processing of water-supply wells and potable water systems by ozone in order to provide disinfection and decontamination.

To achieve this aim recommended value of the following parameters are established: time of processing, ozone concentration in gas mixture, ozone consumption and gas mixture consumption.

Main part. To determine ozone solvability in water from top to bottom of liquid column test setup that looks like a plastic pipe in diameter of 0.3 m and in height of 5 m was used. The pipe has got sampling fitting spaced at intervals of 1 m. ozonic and gaseous mixture fitting is situated at the bottom of the pipe.

Water for experiment was delivered into the pipe from water-supply wells (water supply point Urovtsy, Belostok, Poland). During the experiment the temperature of the water was 10–12°C.

During the trials ozonator of the company Finnegan-Reztek (USA) was used for generation of ozone.

Evaluation of ozone concentration in the water was carried out according to NSS 18301–72 "Potable water. Evaluation of residual ozone content tests". Test sensitivity 0.05 mg O_3/l.

During the testing the following parameters of water treating were set: ozone concentration in gas mixture – 35, 45, 55 g/m^3; processing time – 15, 30, 45, 60 min; gas mixture consumption – 700 l/h.

Table 1

Comparative analysis of different disinfectants all over the world

Country	Cl_{2+}	ClO_2	NH_2Cl	O_3	UV
Australia	+++	+	++	–	+
Austria	+++	+		+	+
Belgium	+++	+	–	+	
Bulgaria	+++	–	–	–	+
China	+++	–	–	+	–
The Czech Republic	+++	–	–	+	–
Finland	+++	+	+	+	–
France	++	++	–	++	–
Spain	+++	+	–	++	–
Ireland	+++	–	–	+	–
Japan	+++	–	–		–
Germany	+++	+++	–	++	+
Norway	++	–	+	–	++
Poland	+++	+	+	+	–
South Africa	+++	–	+	+	–
Switzerland	+	++	–	++	++
Sweden	+++	+	++	–	–
The USA	+++	+	+	+	+
Hungary	+++	–	+	+	–
Great Britain	+++	+	+	–	+
Italy	+++	+++	–	–	–

Note. *+++ – dominating application; ++ – applied; + – rarely applied; – – not applied.*

For evaluation of effectiveness of disinfection bacteria from the collection of the bioengineering and bioecology professorial chairs of BSTU were used as test-organisms: *Clostridium sp.* (sulfite-reducing bacteria, gram-positive, obligate anaerobes, rod bacteria, sporogenous; their presence in tap water testifies of poor level of disinfection); *Pseudomonas fluorescens* (gram-negative, aerobic, nonspore-forming bacteria capable for degradation of halogen-containing organic substances, they synthesize green pigment that provides proper visualization of colonies); *Escherichia coli* (gram-negative rod bacterium widely occurs in endgut of homothermal organisms, facultative anaerobe does not form endospores; it is an indicator of secondary pollution of tap water by residential waste water).

To carry out microbiological testing experimental ozonator made by OSC “RovalantSpetsService” [8] with ozone concentration output in gas mixture of 2.6 g/m^3 was used.

Statistical analysis of the results of the tests was carried out by MathLab software package.

Results and discussion. Saturation time was evaluated in conformity with the research results of saturation kinetics of water with ozone; evaluation of residual ozone content in water out of initial ozone delivered into system, dynamics of ozone decomposition in water and also time necessary to achieve 100% destroying of studied bacteria strains.

According to the data provided in the source [7] and also calculation data of residual ozone content in water out of initial ozone delivered into system (Fig. 1) it is possible to conclude that recommended processing time is 25 min.

According to the research on evaluation of ozone kinetic decomposition from top to bottom of liquid column, about 96% of it decomposes after 20 min (Fig. 2).

Results of the research of the effectiveness of disinfection of tap water by chlorine-containing reagents have revealed that at recommended by SanRaN conditions of processing (6 h at active chlorine concentrations of 50–100 mg/l) 100% disinfection of water for all studied test-organisms from the collection of the bioengineering and bioecology professorial chairs of BSTU was provided. Decrease of time processing to 0.5–1.5 h resulted to decrease of effectiveness of disinfection by sodim hypochlorite of water polluted by bacteria *E. coli*, by 0.5–1.0% whilst calcium hypochlorite effectiveness preserved. Similar behavior was observed at the usage of chlorine-containing disinfecting agents against *Clostridium sp.* и *Pseudomonas fluorescens* bacteria.

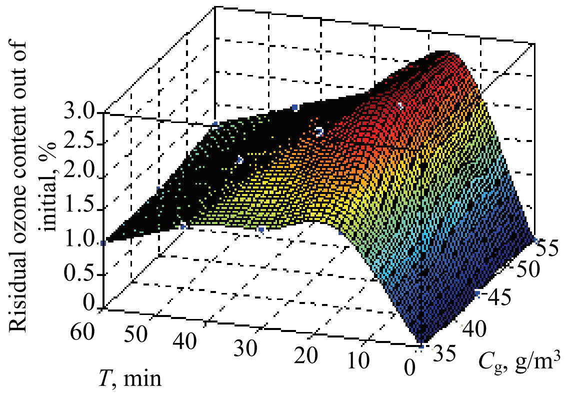

Fig. 1. Risidual ozone content out of initial delivered into water from top to bottom liquid column at its different initialconcentration in gas mixture

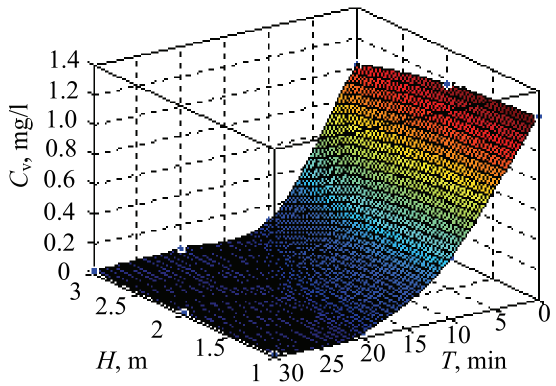

Fig. 2. Destruction of decomposed ozone in water From top to bottom of liquid column

Results of the research of the effectiveness of disinfection by ozone on tested bacteria are in Table 2.

According to Table 2 ideal processing time necessary to achieve 100% destroying of tested microorganisms is less than 5 min.

Disinfection time will be limited by dissolution rate of ozone in water until achieving of necessary minimal concentration. Consumption of gas mixture and ozone concentration in it will influence saturation time.

As for gas mixture consumption (under equal conditions of dispergating) the more it is the biggest the effectiveness of ozone dissolution in water due to the increase of the surface of mass exchange in the form of gas bubbles surface and correspondently the less time it will take.

Table 2

Ozone disinfection effectiveness, %

Gas consumption, l/min	Processing time, min			
	0.33	0.66	1	5
Escherichia coli				
13.2	30.8	68.1	100.0	100.0
8.8	30.8	57.7	100.0	100.0
4.4	3.8	26.9	98.7	100.0
Clostridium sp.				
13.2	99.8	99.9	100.0	100.0
8.8	70.8	87.0	99.8	100.0
4.4	48.9	67.6	98.4	100.0
Pseudomonas fluorescens				
13.2	76.4	92.0	98.9	100.0
8.8	48.3	78.7	93.0	100.0
4.4	28.0	61.2	76.5	100.0

According to [9], size of gas bubbles forming at the usage of ceramic aerators is 5 mm.

For establishment of ideal concentration of ozone in gas mixture results of the test at saturation time of 15 min were taken. They are in Fig. 3.

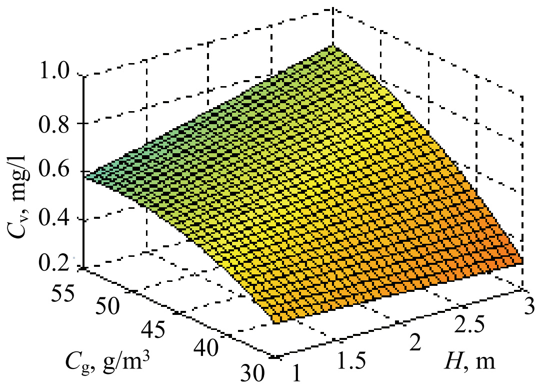

Fig. 3. Dependence of ozone concentration in water on ozone concentration in gas mixture and liquid layer height

According to the obtained results of this paper it is possible to make a conclusion that usage of air-operating ozonators as feed gas with ozone concentration in gas more than 45 g/m^3 is recommended.

Conclusion. Under operating conditions usage of air-operating ozonators working on air as feed gas with ozone concentration in gas of more than 45 g/m^3 is of priority and recommended time of processing of water-supply facilities is 20–25 min

References

1. Italian Regulation. ACCORDO tra Ministro della Salute, le Regioni e le Province Autonome di Trento e Bolzano, sugli aspetti igienico sanitari concernenti la costruzione, la manutenzione e la vigilanza delle piscine ad uso natatorio. Gazzetta Ufficiale della Repubblica Italiana, del. 3.3.2003, n. 51.

2. Rossi G., Comuzzi C., Barbone F., Goi D. Experimental tests for ozone disinfection treatment in a small backyard swimming-pool. J. Waste Water Treatment Analysis 1:105, vol. 1, issue 2, p. 126.

3. Tripathi S., Tripathi D. M., Tripathi B. D. Removal of organic content and color from secondary treated wastewater in reference with toxic potential of ozone during ozonation. Hydrol current, res. 2, p. 111.

4. Christopher R. Schulz, Stephen R. Lohman. Method and apparatus for ozone disinfection of water supply pipelines. Patent US, no. 20050249631, 2005.

5. Leszczyński A. Ocena efektywnosci dezynfekcji studni glebinowych i rurociagow metoda ozonowania: praca dyplomowa magisterska. Bialystok, 2013. 121 s.

6. Ramanouski V. I., Hurynovich A. D., Chaika Y. N., Wawzhenyuk P. Ozone disinfection of water intake wells and pipelines of drinking water supply systems. *Proceedings of BSTU. Chemistry and technology of inorganic substances*, 2013, no. 3, pp. 51–56.

7. Ramanouski V. I., Hurynovich A. D., Wawzhenyuk P. The effectiveness of the ozone use in water treatment technology. *Vodoochistka* [Water treatment], 2014, no. 2, pp. 66–70 (in Russian).

8. Dmitriev C. M., Kondrat'ev M. P. *Generator ozona* [Ozone generator]. Patent BY, no. 2003040115, 2005.

9. Sander M. *Tekhnicheskoe osnashchenie akvariuma* [Technical equipment of aquarium]. Moscow, Publisher Astrel′, 2004. 256 p.

Information about the authors

Ramanouski Valiantsin Ivanavich – Ph. D. Engineering, senior lecturer, Department of Industrial Ecology. Belarusian State Technological University (13a, Sverdlova str., 220006, Minsk, Republic of Belarus). E-mail: V.Romanovski@yandex.ru

Likhavitski Vitaliy Viktorovich – assistant, Department of Automation of Production Process and Electrical Engineering. Belarusian State Technological University (13a, Sverdlova str., 220006, Minsk, Republic of Belarus). E-mail: likh@tut.by

Rymovskaya Marya Vasil'evna – Ph. D. Engineering, assistant, Department of Biotechnology and Bioecology. Belarusian State Technological University (13a, Sverdlova str., 220006, Minsk, Republic of Belarus). E-mail: rymovskaya_mv@mail.ru

Hurynovich Anatoliy Dmitrievich – D. Sc. Engineering, professor, professor, Department of Construction Economics. Belarusian National Technical University (65, Nezavisimosty Ave., 220013, Minsk, Republic of Belarus). E-mail: Gurik@bk.ru

Received 20.02.2015