A.D. Hurynovich • V.I. Romanovski • P. Wawrzeniuk

ANALYSES OF EFFECTIVENESS OF ACTION CASCADE OZONE GENERATOR

A.D. Hurynovich, P. Wawrzeniuk – Department of Engineering Systems in Environment Protection, Technical University of Bialystok
V.I. Romanovski – Department of Industrial Ecology, the Belarus State Technological University,

adrey korespondencyjne:

Department of Engineering Systems in Environment Protection, Technical University of Bialystok,
Wiejska 45, Bialystok, Poland
e-mail: gurinowitsch@tut.by

Department of Industrial Ecology, the Belarus State Technological University
Sverdlova, 13a, Minsk - 220050, Belarus
e-mail: ValSc@tut.by

ANALIZA EFEKTYWNOŚCI KASKADOWEGO GENERATORA OZONU

STRESZCZENIE: W artykule przedstawiono główne obszary zastosowania ozonu do oczyszczania wody., oraz podstawowe parametry dezynfekcji wody. Dane doświadczalne dotyczące rozpuszczalności ozonu w wodzie za pomocą kaskadowego turboozonator, w zależności od stężenia ozonu w fazie gazowej, przepływu mieszaniny gazu i czasu trwania dezynfekcji.

SŁOWA KLUCZOWE: Ozon, ozonowanie, rozpuszczalność, woda, dezynfekcja

Introduction

The most widespread application of ozone – water treating. Ozone effectively destroys bacteria and viruses, eliminates organic pollution of water, destroys smells, can be used as bleaching reagent.

In the field of water preparation ozone is used in several directions:

– clearing of potable water from superficial or underground sources;
– sewage water treatment[1];
– water treating in systems of turnaround water supply of pools[2].

Ozonization is one of most ecologically pure and universal methods of water treating.

In the world for today the set of systems the water preparations using ozonization works: in France, Canada, Switzerland, Italy, Germany, Saudi Arabia, etc. However because of relative dearness of the equipment, severity of technology and astable quality of the let out equipment ozonization long remains at experiment level.

Ozone doses, depending on structure of processed water, make from 0.5 to 5 mg/l, time of reaction of an ozono-air mix with water for effective oxidation of impurity – from 1–2 to 10–15 min. According to the instructions on the maximum microbiological contamination given by the Italian rules and standards of 10^3 CFU/ml bacterial concentrations can be dezinfetsirovany minimum amount of dissolved ozone O_3 0.2 mg/l for 5–15 sec[3].

Thus, along with doubtless advantages as the most effective, complex and natural reagent, ozone has also lacks. Ozonization cannot be the unique universal method of water treating relieving it from all possible pollution, and is only one of water preparation steps. Besides, ozone application imposes some technological restrictions.

First, because of saturation of water by an ozono-air mix it gets high oxidising ability and becomes corrozion-active. Especially corrosion activity can increase at rise in temperature or pressure decrease in system (solubility of oxygen

[1] Tripathi S, Tripathi DM, Tripathi BD (2011) *Removal of Organic Content and Color from Secondary Treated Wastewater in Reference with Toxic Potential of Ozone During Ozonation*. Hydrol Current Res 2, 111. doi:10.4172/2157-7587.1000111; Kim I, Tanaka H (2010) *Use of ozone-based processes for the removal of pharmaceuticals detected in a wastewater treatment plant.* Water Environ Res 82, 294–301; Guo Y, Yang L, Cheng X, Wang X (2012) *The Application and Reaction Mechanism of Catalytic Ozonation in Water Treatment.* J Environ Anal Toxicol 2:150. doi:10.4172/2161-0525.1000150.

[2] Rossi G, Comuzzi C, Barbone F, Goi D (2010) *Experimental Tests for Ozone Disinfection Treatment In a Small Backyard Swimming-Pool.* J Waste Water Treatment Analysis 1:105. Vol. 1. Issue 2. doi:10.4172/2157-7587.1000105.

[3] Italian Regulation (2003) 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.

in water falls). It demands use of the equipment and the materials proof to ozone (pipes from PVC or stainless steel, reactors and capacities for storage of the ozonized water from PVC or concrete), etc.

Secondly, ozonization is the process demanding certain structure of the equipment:

- ozone-generator in which development of ozone from air or oxygen is carried out;
- system of introduction of ozone in water and its mixtures;
- a reactor – capacity in which at the expense of hashing and endurance necessary time of reaction of ozone with water is provided;
- ozone distructor for removal of the residual not reacted ozone;
- devices of the control of ozone in water and air.

Thirdly, there are restrictions by quantity of ozone in water (a dose of residual ozone no more than 0,1 mg/l) and in air (ozone maximum concentration limit indoors where people work, – no more than 160 mkg/m^3).

However experience of use of ozonization at the present stage, saved up for systems of different productivity, says that this technology is possible and it is necessary to apply not only on the powerful waterworks which is responsible for supply by water of large cities, but also in systems of water preparation of small and average productivity.

Undoubtedly, that quality of water by water preparation with ozonization use will be considerable above, than at other technologies, however an economic estimation it is possible to subject this parameter only in turnaround systems. One more advantage of use of ozonization is that at rather high cost of primary capital expenses operational expenses are connected only with a current consumption (on the average 0.02 kW on 1 g ozone)[4].

There is an opinion, that ozonization is much more expensive than chlorination. However it not so. In the course of chlorination there is a necessity to eliminate excessive chlorine from water, to spend so-called dechlorination. For reception of water of satisfactory quality it is necessary to do it, applying special reagents. Taking into account this factor, and also tendencies of continuous fall of the price on ozon equipment and increase of the price for chlorine and a chlorine-products, now cost of these processes it is almost comparable. As it was specified in the second section, chlorination is used more often, than ozonization[5]. For this purpose two reasons. Simplicity of work with chlorine (if it is a question of cylinders with liquid chlorine). It, certainly, easier than to watch concentration of the ozone leaving an ozonizer, considering, that an ozonizer

[4] Romanovski V.I., Gurinovich A.D., Kunitskaja I.D., Lihavitsky V.V. (2012) *Research of technical characteristics turboozonizer with a high-frequency resonant electroionization ozone generator.* The conference proceedings Eastern European Young and Senior Water Professionals Conference. St. Petersburg, Russia 4–6 October 2012. Part 1, 244–247.

[5] Zhang X (2012) *Which Drinking Water Disinfection Process Generates the Least Toxic DBP Mixture: Chlorination, Chloramination, Ozonation, or Chlorine Dioxide Treatment?* J Civil Environment Engg 2:e105. doi:10.4172/2165-784X.1000e105.

rather difficult device and it is necessary to be assured, that it unexpectedly will not be disconnected. Till the latest time reliability ozone equipment left much to be desired, and low level of automation assumed necessity of use of attendants concerning high qualification, however modern ozonizers are reliable enough and simple in operation that should open it road on the market.

Experiment techniques

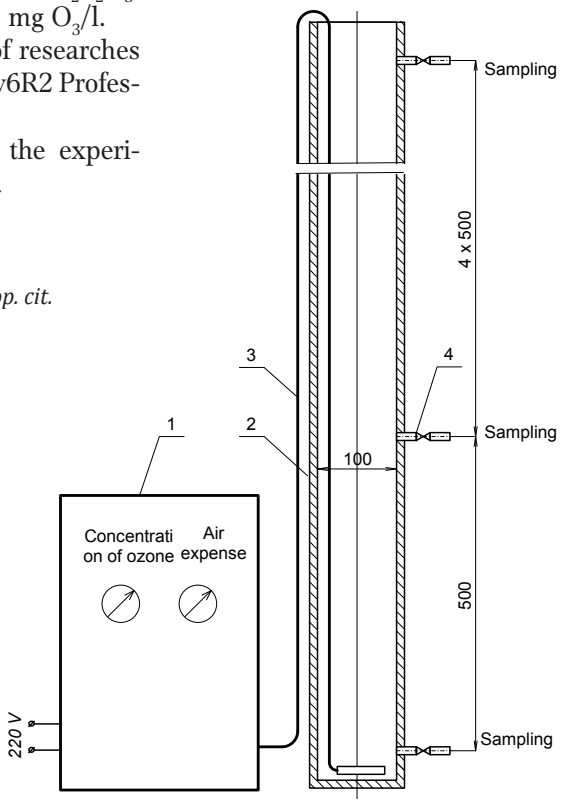
For research of solubility of ozone in water and definition of concentration of ozone on height of a column of a liquid the installation represented in Figure 1 has been collected.

Definition of concentration of ozone in water spent on GOST 18301-72 "Water drinking. Methods of definition of the maintenance of residual ozone". Definition is based on oxidation by ozone iodid to iodine, which titrate to solutions $Na_2S_2O_3$. Sensitivity of a method of 0,05 mg O_3/l.

For processing of results of researches used software package S-Plus v6R2 Professional.

Ozone generator used in the experiment – experimental VGO 15[6].

Figure 1
The installation scheme



1 – an ozonizer; 2 – a pipe; 3 – flue; 4 – the sampling union.

[6] Romanovski V.I. at all, *Research..., op. cit.*

Results and discussion

For today there is a set of various types of ozonizers. The basic directions of development of systems of ozonization are search of ways of increase of their productivity and decrease in power inputs on ozone manufacture. In the Republic of Belarus was developed new cascade turboozonizer VGO-15 (Figure 2) with high-frequency resonant electroionization the generator of ozone[7].

Figure 2
Cascade turboozonizer VGO-15

The one of the purpose of the given work consisted in definition of key parametres developed experimental cascade turboozonizer VGO-15.

Parametres after specification:

Concentration of ozone (g/m^3):

- The minimum value (at Q_{max}, C_{min}) – 0,320 g/m^3;
- The maximum value (at $Q_{max}/4$, C_{max}) – 17,750 g/m^3;

The expense of gas (l/min):

- The maximum value (at C_{O3min}) – 13,2 l/min;
- The maximum value (at C_{O3max}) – 12,9 l/min;

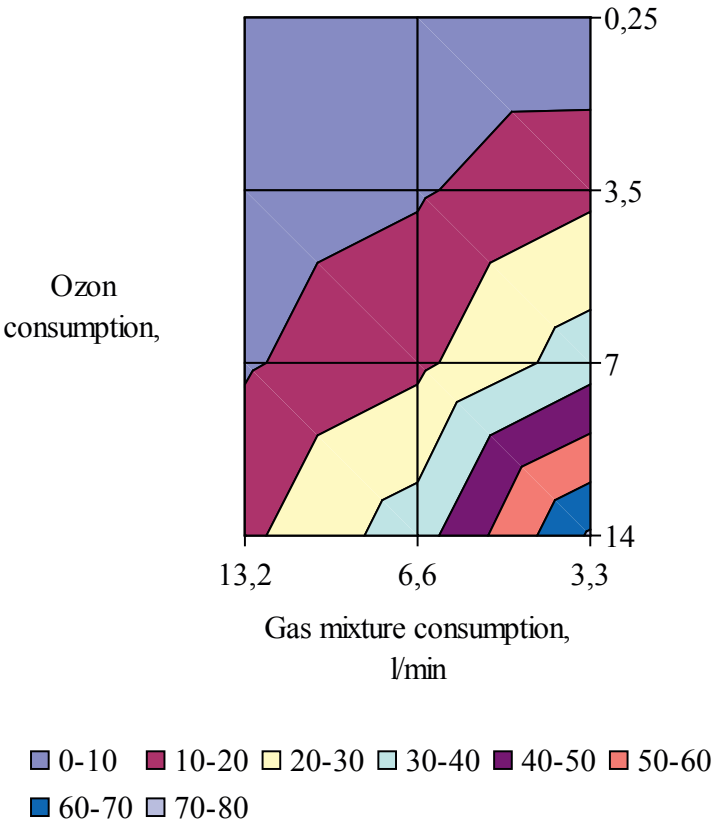
The maximum productivity on ozone – 14,0 g/hour.

Specific power inputs on manufacture 1 g O_3 ($W \cdot hour/g\ O_3$) depending on an ozonizer operating mode are presented in Figure 3.

[7] Patent BY 1991 (2005). Ozone generator. / Dmitriev S.M., Kondratiev M.P. 2005.06.30.

Constructive decisions and the technologies applied in cascade turboozonizer, provide high efficiency and low power consumption, universality of application thanks to a cascade set of capacities, low cost of the equipment, installation and maintenance service, and also high reliability and long service life.

Figure 3
Specific power inputs on manufacture 1 g O_3 (W·hour/g O_3)
depending on an ozonizer operating mode



Solubility of ozone in water depends on many factors, but first of all from concentration of ozone in ozone-oxygen mixes, and also water temperatures (in experiment water with temperature 17°C was used). Ozonization time is defined by speed of giving of a mix, volume of ozonized water, a reactor design.

In Figures 4 and 5 data on saturation of water by ozone are presented at its identical expense in unit of time (14,0 g/hour) and various expenses of a gas mix in a current of 10 and 60 min of processing.

Figure 4
Concentration of ozone in processed water, mg/l, from the expense of a gas mix at the expense of ozone 14,0 g/hour, and time of processing of 10 min

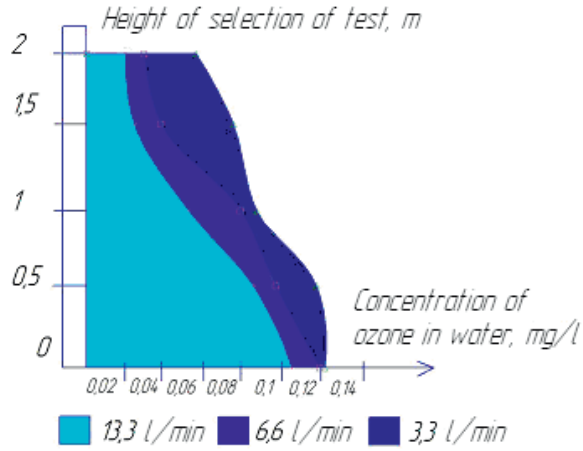
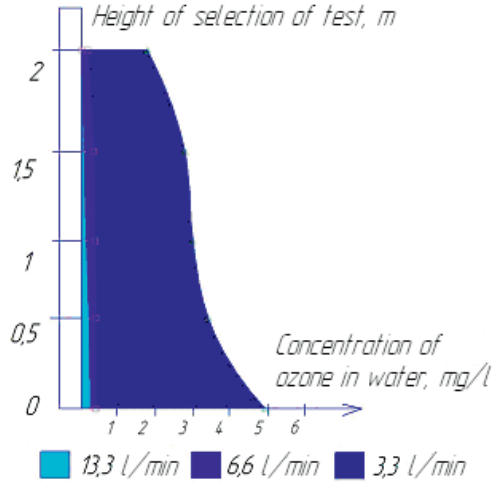


Figure 5
Concentration of ozone in processed water, mg/l, from the expense of a gas mix at the expense of ozone 14,0 g/hour, and time of processing of 60 min



From drawings it is visible, that on saturation of water by ozone influences its concentration in a gas mix and a surface of mass exchange, created by air dispersant. The maximum saturation of water is created at большей concentration of ozone in a gas mix (the expense of ozone 14,0 g/hour, the expense of a gas mix of 3,3 l/min) and makes 4,9 mg/l that confirms known laws.

In Figures 6 and 7 data on saturation of water by ozone depending on processing time are presented.

Figure 6
Concentration of ozone in processed water, mg/l, from processing time at the expense of ozone 14,0 g/hour, a gas mix – 13,2 l/min

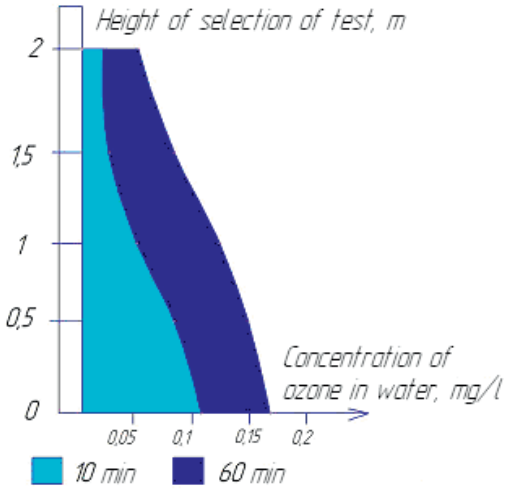
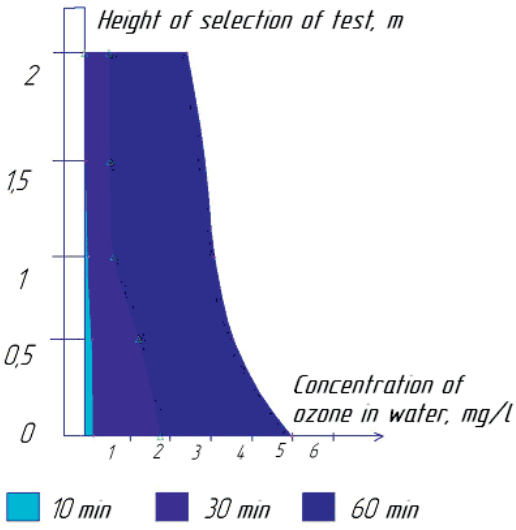


Figure 7
Concentration of ozone in processed water, mg/l, from processing time at the expense of ozone 14,0 g/hour, a gas mix – 3,3 l/min



Proceeding from the received laws of saturation of water ozone follows, that at ozonization of a sheet of water dispersant it is necessary to have on certain distance on height (nearby 5–7 m).

Found that saturation of water with ozone affects the concentration in the gas mixture and the surface mass transfer (size of gas bubbles created by air "dispersant"). Maximum saturation of water created when a higher concentration of ozone in the gas mixture and lower its costs, increase processing time, which confirms the known laws.

At saturation, tap water (temperature 17°C) to ozone concentration of 4 mg/l, 50% of the decomposition was observed after 40 min.

Conclusions

For effective disinfection or disinfection is necessary to create the ozone concentration in the water more than 0.05 mg/l8 and to maintain it for a few minutes. Ozone can be used for pre-treatment of water in order to convert the dissolved substances in colloidal form with subsequent deposition on the filter, as it has the effect of flocculation. According to its bactericidal effects ozone are in 3–6 times more effective than ultraviolet radiation and in 400–600 times effective than chlorine.

The advantage of ozone is that, ozone disinfection takes place simultaneously with the discoloration of water and eliminates odors and flavors of water and generally improve its taste. Ozone does not change the natural properties of water as its excess (unreacted ozone) in a few minutes turns into oxygen. Disinfection process will take several minutes, not hours, as in ispolhovanii chlorinated chemicals.

Before recommending the use of ozone is necessary to scale tests. At their processing it is necessary to consider the bottom concentration limit of explosibility ozone in air which makes 10% or 146/m^3.

[8] Italian Regulation (2003) ACCORDO..., *op. cit.*