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EFFECT OF USED SOLUTIONS FOR DRINKING WATER SUPPLY FACILITIES DISINFECTION TO SOIL

Use of a composition of active chlorine bleach, calcium and sodium hypochlorite for disinfection of water supply facilities connected with disposal of waste solutions, any variant causes their transfer into the environment.

The effect of solution for disinfection of drinking water supply facilities using active chlorine and ozone to the ground has been studied in terms of actual and potential dehydrogenase and catalase activity, and biomass plants. The change of the component composition of the soil and the reduction of the respiratory activity of its microbiota using bleach and sodium hypochlorite for disinfection of water supply facilities is studied, while the residual ozone leads to the activation of organic compounds oxidation processes and to less significant transformation of organic matter in the soil.

Systematically polluted by waste solution with active chlorine soils must be subjected to remediation, preferably by active soil bacteria or specialized bacterial strains, which are capable to degradation of organochlorine substances.

The use of ozone for the disinfection of drinking water supply facilities will reduce the environmental burden to surrounding area soils.

Key words: disinfection, water treatment facility, active chlorine, ozone, soil, dehydrogenase activity, catalase activity, bioremediation.

Introduction. Groundwater is a main source of water supply in the Republic of Belarus. There are nearly 32 thous. of water boreholes, most of which are in poor condition and more than one-third of which went down [1]. According to data provided in [2], from 44 816 reservoirs of decentralized supply sources of clean household and drinking water registered by the government (as a rule it concerns dug well), for the beginning of 2012, 8.1% of such reservoirs do not meet the requirements on the structure, 26% are inadequate to hygienic measures in chemical composition, 10.3% are not in line with quality standards in terms of microbiological characteristics.

The main, and often the only problem of groundwater resources deterioration is sanitary and technical conditions of water intakes and adjoining territories caused by usage of mineral and organic fertilizers in cultivated ploughed fields, territorial development, close location of cesspools, sheds and dump sites. In accordance with the current sanitary rules and regulations "Sanitary-epidemiological requirements to the centralized systems of drinking and household water supply" [3] disinfection of inner surface of water supply facilities with the help of chlorine-containing reagents with the available chlorine concentration of 50–100 mg/l during 6–24 h is required.

At the same time it becomes necessary to utilize disposal solution of available chlorine reagents. However sanitary rules and regulations [3] don't provide with clear indications but recommend disposing chlorine and rinsing water in accordance with water supply project. Such a disposal in a storm drain or waste water disposal system can lead to water ingress in reservoirs or to dysfunction of local biological treatment plants. Water extraction at a location leads to interaction of available chlorine with organic component of soil ground. The result is a chlorinated organic component of different structure that pollute surface and ground waters.

In recent years for the purpose of water treatment, ozone along with chlorine-containing disinfectants became widespread abroad [4]. Residual ozone concentration in water after disinfection of constructions with ozone-air mixture, rapidly decrease and in terms of conditioning after processing is equal to 0.005 mg/l that refers to little impact of such water on environment. Also the evaluation of importance of potential impacts on environment was carried out [5]. The results of the environmental and health effects (carcinogenic effect, respiratory effect, ozone layer depletion, ecotoxicity of water and land resources, etc.) considering the importance of each category, have shown that the lowest value of eco-indicator is consistent to the variant of ozone solution usage in water. In addition, of all the chlorine-containing substances, hypochlorite of sodium is the best substance [6]. Based on the results of technical-and-economic indexes without including factor of time, disinfection technology with ozone usage is economically efficient. Bearing in mind the time factor, it is compared with the cost. The main part of current expenditures with chlorine-containing reagents usage, are the costs of raw and other materials, without chlorine-containing reagents usage – amortization expenses [6]. The objective was studying the effect of chlorine-containing and ozone solutions for disinfection on the soil ground. The aim was studying solutions effect on the soil ground; modeling of different bioremediation ways; studying solid recovery characteristics; suggestion of technology remediation of soil ground. The subject of research was sod podzolic sandy clay on unconsolidated sandy soil, treated with disinfection solutions for water supply facilities disinfection.

Materials, reagents and equipment. The process of soil ground pollution was modeled by its disinfection with lime chloride solution and hypochlorite of sodium with initial dose of 100 mg/l, and ozonized water with 2 mg/l of ozone concentration, 10 ml per 40 g tight soil.

The choice of concentration is caused by the doses of reagents recommended for treatment of water supply facilities. The soil treated with the same amount of settled sewage served as the target value. Treatment effect on biochemical processes in soil was estimated according to the indexes of relevant and potential dehydrogenases and catalase activeties [7]. The quantity of chlorinated derivatives in soil was estimated by stratigraphic analysis of hexane extraction of soil [8] with the flame ionization detector. Soil treatment effect on plants was estimated with the seeds of oil radish *Raphanussativus var. oleiferus* (farming enterprise “Novoberezovsko”, Berezovka village, Minsk region, Belarus). The average dry and wet matter of plants was defined on the 20^{th} days.

In order to model bioremediation process of cultivated soil three methods were used: application of organo-mineral fertilizers for microbiota activation, an application of soil microorganisms as a part of commercial medicine to increase bacteria concentration that are used for an active mineralization of organic components of the soil, plants cultivation that helps to improve soil structure, organic and mineral substances. Oxidative turf “Hazon” (Close Joint-Stock Company “Unatex”, Minsk, Belarus) was used in a recommended dose of 1ml/kg as an organo-mineral fertilizer. Commercial chemical “Bionix eco compost” (“BIONETIX, Quebec, Canada) was used in a dose of 0.5 g/kg as a source of microorganisms. Oil radish *Raphanussativus var. oleiferus* was used as a plant that has a positive effect on the soil structure (20 items per 40 g of soil). Cultivated soil without remediation was a determining factor. The experiment duration was 20 days. During this period solid watering with settled sewage was carried out every two days till the full maximum water holding capacity. For the study ozonizer with exit ozone concentration in mixed gas 2.6 g/m^3 [9] of ltd. “RovalantSpezService” company was used.

The results and their discussion. Research results on solution effect containing active oxidizing agents for disinfection of water supply facilities are presented in Table 1.

Table 1

Absolute values of fermentative soil activity after double solution treatment for disinfection of water supply facilities

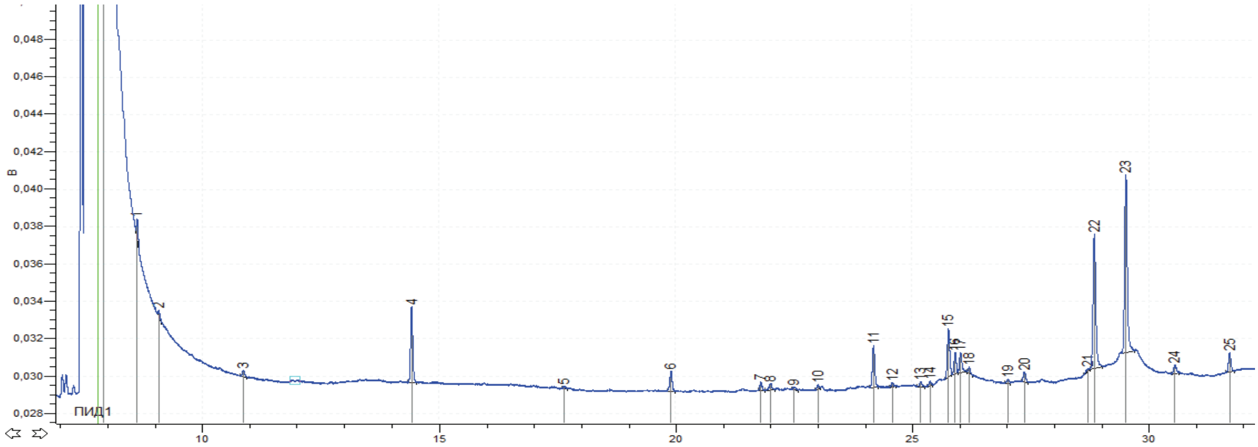
Active substance during sample processing	Catalase activity, ml O_2/min	Dehydrogenase activity, μl H/g	
		relevant	potential
CaOCl	3.7	24.5	92.2
NaOCl	2.5	23.2	101.1
O_3	3.2	30.3	87.4
Without treatment	3.7	29.0	78.9

For easier comparison, empirical value change of fermentative activity in comparison with target value was counted, since fermentative activity values have different dimension and meaning. Single soil treatment by disinfection solutions of water supply facilities demonstrates potential increase of dehydrogenase activity for chlorine solution to 6–10% and to 20–40% for hypochlorite of sodium and ozone. That is due to soil organic matter restructuring and can lead to accessibility for bacteria.

Double treatment, except of chlorine solution treatment (17%), doesn’t lead to significant increase of potential dehydrogenase activity in comparison with single treatment. That is connected with the limited amount of readily oxidizable substances in soil.

At the same time potential activity is still 10–30% more in comparison with the target value, while relevant dehydrogenase activity decreases in comparison with target value of chlorine-containing reagents and is higher for ozone (15, 20 and 5%). Chlorine-containing reagents creation due to chlorine-organic compounds and active oxygen interaction could indicate about suppression of respiratory activity. Catalase activity decrease in comparison with target value is insignificant. That may be an indication of both active oxidizer quantity decrease and activity suppression of respiratory system in a cell. Chromatographic procedure of prepared hexane soil essence that is treated with chloride lime and of uncultivated soil sample (Figure) on gas-liquid chromatograph with flame ionization detector, which unselectively shows all the organic compounds of soil extract, has shown the difference in checked area that reflects new, probably chlorine-containing organic compounds.

The results of the experiment are in Table 2.



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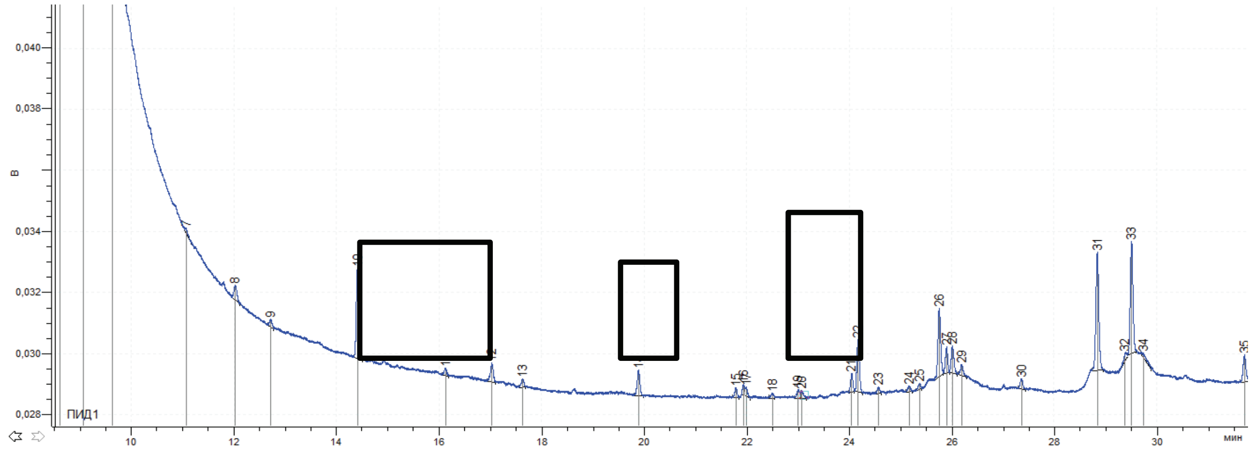

b

Chromatogram of prepared hexane extract treated (*a*) untreated (*b*) soil

Table 2

The results of the study on effect of active disinfection agents on plants

Sample name	Averaged mass of a plant, g	Averaged plant mass by absolutely dry matter, g	Dry matter in plant mass, %
Without remediation			
CaOCl	0.254 ± 0.035	0.012 ± 0.002	4.8
NaOCl	0.255 ± 0.037	0.011 ± 0.002	4.2
O_3	0.310 ± 0.032	0.012 ± 0.002	3.9
Organomineral fertilizer			
CaOCl	0.288 ± 0.057	0.011 ± 0.001	3.6
NaOCl	0.395 ± 0.083	0.009 ± 0.002	2.2
O_3	0.244 ± 0.060	0.010 ± 0.001	4.0
Plant cultivation			
CaOCl	0.173 ± 0.026	0.014 ± 0.002	4.9
NaOCl	0.242 ± 0.042	0.010 ± 0.001	4.2
O_3	0.190 ± 0.041	0.007 ± 0.002	3.6
Soil bacteria product application			
CaOCl	0.257 ± 0.041	0.008 ± 0.002	3.0
NaOCl	0.284 ± 0.046	0.007 ± 0.001	2.4
O_3	0.180 ± 0.025	0.008 ± 0.001	4.7
Without disinfection			
Monitoring	0.260 ± 0.058	0.008 ± 0.001	2.9

The analysis of data has shown that the differences in most cases are statistically unreliable. However the tendency to accelerated growth of plants in the presence of chlorine compound and ozone dry mass is quite significant.

Moreover soil after treatment by remediation in most of the cases decrease dry mass of plants.

The analysis of dry mass percentage in a plant mass has shown that soil treatment by active chlorine and ozone causes dry mass increase in plant biomass (3.9–4.8% against 2.7% for untreated soil). That indicates on more intensive metabolic process. This can be connected with combustion of active oxidizers that makes biogenic elements plant-available.

In case of ozone water treatment none of the remediation factors have an effect, while chlorine fertilization caused decrease of dry matters in plant biomass. Probably increasing the number of active chlorine and ozone product treatment would show more clear vision. Fermentation activity of polluted soil that were treated using bioremediation, are in Table 3.

Almost in all cases there is a relevant soil activity increase. That indicates beneficial effect of all three soil remediation factors. Potential activity increase can be clearer in case of active decomposers application. That shows the preference of the method.

For each variant of remediation treatment, catalase activity changes within the limits of experimental error. It suggests little remediation impact on enzyme system.

The combination of the studied remediation methods allows taking advantages of all. From the studied soil remediation factors more evident effect had microorganism application (application of organic substance decomposers).

Supplemental application of organic and mineral fertilizers (biogenic elements) in soil will also have a beneficial effect due to microorganism activity. Further enhancement effect of remediation is possible in the absence of growth limitation of plants on treated area.

Table 3

Fermentation activity change of soil after double disinfection of water supply facilities in comparison with target value (untreated soil) before and after remediation

Disinfecting agent	Catalase activity	Dehydrogenase activity	
		relevant	potential
Soil without remediation			
CaOCl	0.0	–15.3	16.9
NaOCl	–0.3	–20.0	28.2
O_3	–0.1	4.7	10.8
Organo-mineral fertilizer application			
CaOCl	–0.2	64.2	38.9
NaOCl	0.0	–20.8	5.9
O_3	0.2	76.3	32.7
Plant cultivation			
CaOCl	–0.1	49.3	122.6
NaOCl	–0.2	109.0	51.0
O_3	0.2	190.0	5.6
Soil bacteria products application			
CaOCl	0.0	109.7	172.7
NaOCl	–0.1	29.0	50.0
O_3	0.2	–1.6	0.0

Conclusion. Lime chloride and sodium hypochlorite as a part of spent solutions for disinfection of water boreholes lead to component composition change of soil and to microbiota respiratory activity decrease, while remaining ozone leads to oxidation process activation of organic substances.

Soil with consistent application of active chore substances, is subject to reme-diation, preferably with active bacteria usage (as a part of chemical product or special strain that are able to decompose chlorinated derivatives). The use of ozone for disinfection of water supply facilities will allow decreasing environmental pressure on surrounding area.

References

1. *Gosudarstvennyy vodnyy kadastr. Vodnye resursy, ikh ispol'zovanie i kachestvo vod* [State water cadastre. Water resources, their use and water quality]. Minsk, 2012. 144 p.

2. *Sostoyanie prirodnoy sredy Belarusi: ekologicheskiy byulleten 2012* [State of the environment of Belarus: ecological bulletin 2012]. Ed. by V. F. Loginov. Minsk, RUE "Minsktipproekt", 2013. 378 p.

3. *Sanitarnye normy i pravila "Sanitarno-epidemiologicheskie trebovaniya k sistemam tsentralizovannogo khozyaystvenno-pit'evogo vodosnabzheniya"* [Sanitary regulations "Sanitary-epidemiological requirements for centralized drinking water supply"]. Minsk, Ministerstvo zdravookhraneniya Respubliki Belarus' Publ., 2014. 20 p.

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

5. STB ISO/TO 14049-2007. Environmental management. Life cycle assessment. Adaptation of STB ISO 14041-2001 for the life cycle inventory analysis. Minsk, Gos. komitet po standartizatsii Publ., 2007. 44 p.

6. Romanovskiy V. I., Bessonova Yu. N. Comparative analysis of water wells disinfection methods and construction of water supply. *Materialy mezhregionalnoy nauchno-tekhnicheskoy konferentsii "Perspektivy razvitiya i organizatsionno-ekonomicheskie problemy upravleniya proizvodstvom" v 2 t. T. 1.* [Materials of the Interregional Scientific and Technical Conference "Prospects of Development and Organization and Economical Problems of Production Management" in 2 vol. Vol. 1]. Minsk, Pravo i ekonomika Publ., 2015, pp. 211–226 (In Russian).

7. Khaziev F. Kh. *Metody pochvennoy enzimologii* [Methods of soil enzymology]. Moscow, Nauka Publ., 1990. 189 p.

8. GOST R 53217-2008. Soil quality. Determination of organochlorine pesticides and polychlorinated biphenyls. Gas chromatographic method with electron capture detector. Moscow: StandartInform Publ., 2009. 20 p.

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

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