Disinfection of wastewater with ultraviolet light on devices of the cyclic principle of action

A S Ovchinnikov, V S Bocharnikov, O V Bocharnikova, E V Pustovalov, M A Denisova and T V Repenko

Volgograd State Agrarian University, 26 University Avenue, Volgograd, 400002, Russia

E-mail: pustovalov-evgeniy@mail.ru

Abstract. The article presents a diagram of a device for ultraviolet disinfection of wastewater of a cyclic principle of action, which allows you to control the time of liquid processing and, accordingly, the dose of ultraviolet radiation. The device consists of the following structural elements: round-section body; ultraviolet lamps attached to the inner surface of the housing walls; inlet and outlet pipelines with shut-off and control valves; level gauge made in the form of a float. One cycle of operation of the device consists of filling the body, processing (disinfecting) the original liquid, and emptying the body. Control tests of this device were carried out in the process of purifying wastewater from a cattle breeding complex. During the tests of this device, it was revealed that the effluents treated with ultraviolet light with a generally accepted radiation dose of 30 mJ/cm² do not meet the requirements of sanitary and hygienic standards, since the number of viable helminth eggs at the outlet is 54.2% of their initial value, and the effect of complete deworming can be achieved only at a dose of ultraviolet radiation of at least 45 mJ/cm².

1. Introduction

Maintaining an environmentally friendly environment is one of the key points in the development and improvement of crop irrigation technologies [1, 2, 3]. Reclamation measures should be aimed not only at increasing soil fertility and productivity of cultivated crops, but also at ensuring a stable ecological environment that does not violate the balance between man and the environment [4, 5, 6, 7].

Particular attention in ensuring environmental safety is paid to the issues of wastewater disposal. Both when discharged into surface water sources and when disposed of in irrigation fields, wastewater in most cases does not meet sanitary standards: the content of oil products, nitrites, sulfates, phenols, heavy metals, etc. is exceeded [8, 9, 10, 11]. Based on this, there is a need to improve the known, as well as the development of new technologies for wastewater treatment, where special attention should be paid to disinfection [12-21].

Currently, the most widespread are disinfection with chemically active components (chlorination and ozonation) and treatment with ultraviolet radiation. Ultraviolet irradiation is considered by most scientists as the most promising way to disinfect wastewater. Firstly, this method of disinfection does not require specially designated areas for storing reagents. Secondly, ultraviolet rays do not change the chemical composition of the processed liquid.
Most of the ultraviolet disinfection devices are based on a flow-through principle of action. The main disadvantage of this constructive solution is the lack of the possibility of regulating the time of bactericidal irradiation and, as a consequence, the dose of ultraviolet irradiation remains constant. In addition, it should be noted that when using such devices for the disinfection of wastewater, the doses of ultraviolet radiation are 30 mJ/cm², which does not satisfy the necessary inactivation of the entire species composition of pathogenic microflora.

2. Materials and methods

To eliminate the disadvantages mentioned above, we have developed an ultraviolet disinfection device, which is based on a cyclic principle of operation, which will ensure control of ultraviolet radiation doses by regulating the contact time of ultraviolet lamps with the processed liquid.

The device consists of the following structural elements: round-section body 1; ultraviolet lamps 2, attached to the inner surface of the walls of the housing; inlet 3 and outlet 4 pipelines with shut-off and control valves 4; a level gauge made in the form of a float (Figure 1). One cycle of operation of the device consists of filling the body, processing (disinfecting) the original liquid, and emptying the body.

![Figure 1. Scheme of the device for ultraviolet disinfection of waste water of the cyclic principle of operation: 1 - sealed housing; 2 - ultraviolet lamps; 3 - liquid supply pipe; 4 - liquid discharge pipe; 5 - shut-off and control valves; 6 - liquid level sensor.](image)

Control tests of this device were carried out in the process of purifying wastewater from a cattle breeding complex. Evaluation of the efficiency of wastewater disinfection was carried out according to the coli-index of viable helminth eggs. For this, liquid samples were taken with a step of 5 mJ/cm², which in time equivalent is equal to 1 second.

3. Results and discussion

Figure 2 shows the dynamics of inactivation of viable helminth eggs.
Figure 2. Dynamics of inactivation of viable eggs of helminths depending on the dose of ultraviolet radiation.

This graph shows that in the first seconds of disinfection, when the ultraviolet radiation dose is small (5-25 mJ/cm²), the degree of death is 4.2-8.3%. At a dose of 30 mJ/cm², which corresponds to flow-through devices, only 45.8% of helminth eggs died. Most of the eggs of helminths (79.2-100.0%) died off at doses of ultraviolet irradiation of 40-45 mJ/cm². The effect of complete deworming is only at 9 seconds of liquid treatment, which corresponds to an irradiation dose of 45 mJ/cm².

4. Conclusion
The effluents treated with ultraviolet light with a radiation dose of 30 mJ/cm² do not meet the requirements of sanitary and hygienic standards, since the number of viable helminth eggs at the outlet is 54.2% of their initial value. Discharge of such effluents into open water sources, as well as their use for irrigation, is contraindicated. The effect of complete deworming can be achieved only by increasing the treatment time of the waste liquid and controlling the doses of ultraviolet radiation. Only those ultraviolet disinfection devices based on a cyclic principle of action are able to provide these conditions.

5. Acknowledgments
The research was carried out within the State Assignment of Ministry of Agriculture of the Russian Federation (theme No. 13/2673)

References
[1] Ovchinnikov A S, Loboyko V F, Bocharnikov V S, Ovcharova A Yu and Fomin S D 2019 State of the small rivers of the Volga basin within the lower Volga IOP Conf. Series: Earth and Environmental Science 341 012107
[2] Ovchinnikov A S, Borodychev V V, Lytov M N, Bocharnikov V S, Fomin S D, Bocharnikova O V and Vorontsova E S 2018 Optimum control model of soil water regime under irrigation Bulgarian J. of Agricultural Science 24 909-913
[3] Kuznetsova N V, Kuznetsov Yu V, Kozinskaya O V and Denisova M A 2020 Influence of hydraulic parameters on irrigation quality Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 2(58) 73-83

[4] Bocharnikov V S, Kozinskaya O V, Denisova M A and Bocharnikova O V 2020 Studies of hydraulic characteristics of a circular sprinkler machine Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 2(58) 319-327

[5] Snipich Yu F, Chelakhov V C and Kozinskaya O V 2019 Quality study of a circular irrigation sprinkler machine Scientific J. of the Russian Research Institute of Melioration Problems 4(36) 43-54

[6] Ovchinnikov A S and Pustovalov E V 2018 Water balance and structure of total water consumption of sarepta mustard when watered with livestock runoff Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 2(50) 118-124

[7] Pustovalov E V 2018 Influence of irrigation by livestock runs on the technological qualities of mustard oil seeds Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 2(50) 181-186

[8] Kolesnikov V A, Nistratov A V, Kolesnikova O Y and Kandelaki G I 2019 Integrated approach to neutralization of wastewater containing copper ions and EDTA ligand News of Higher Education Institutions. Chemistry and Chemical Engineering Series 62 108-114

[9] Kolesnikov V A, Il'in V I, Kapustin Y I, Varaksin S O, Kisilenko P N and Kokarev G A 2007 Flotation Wastewater Treatment of Industrial Enterprises (Moscow: Khimiya)

[10] Kolesnikov V A, Menshutina N V and Desyatov A V 2016 Equipment, Technology and Design of Sewage Treatment Systems (Moscow: new Delhi and NCR plus)

[11] Ksenofontov B S 2013 Intensification of wastewater treatment of engineering industries using ion flotation Sanitary Engineering 5 30-33

[12] Ovchinnikov A S and Pustovalov E V 2017 The results of studies of the use of zeolite-containing rocks as a filter material in the treatment of livestock effluents Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 4(48) 71-77

[13] Rybalova O, Artemiev S, Sarapina M, Tsymbal B, Bakhareva A, Shestopalov O and Filenko O 2018 Development of methods for estimating the environmental risk of degradation of the surface water state Eastern-European J. of Enterprise Technologies 2 4-17

[14] Brasoveanu F, Petru A and Brezeanu L 2012 European policy concerning the protection of the quality of the environmental factor-water Challenges of the Knowledge Society 2 1058-1063

[15] Feng X, Wang X, Chen Z and Chen J 2019 Nitrogen removal from iron oxide red wastewater via partial nitritation-Anammox based on two-stage zeolite biological aerated filter Bioresource Technology 17-24

[16] Matsak A and Tsytlishvili K 2018 Using different filter media of stormwater treatment performance Norwegian J. of Development of the Int. Science 1(20) 19-22

[17] Kochetov G, Prikhna T, Kovalchuk O and Samchenko D 2018 Research of the treatment of depleted nickel-plating electrolytes by the ferritization method Eastern-European J. of Enterprise Technologies 3 52-60

[18] Bocharnikov V S, Kozinskaya O V, Denisova M A and Bocharnikova O V 2020 Study of the modes of sedimentation of the loading using a hydraulic installation Proc. of the Nizhnevolszsky Agrouniversity Complex: Science and Higher Professional Education 1(57) 260-267

[19] Yurchenko I. F. 2020 Development of innovative management systems for agricultural production on reclaimed lands Business. Education. Right 1(50) 42-49

[20] Loiko A V, Shibanov I V, Kagramanov G G and Blanco-Pedrejon A M 2018 Experience in the implementation of membrane technology for purification of artesian waters with a high
content of iron and manganese Water Purification. Water Treatment. Water Supply 4(124) 58-62

[21] Novikova I V, Luneva E N and Gritsay A V 2019 Means and technologies of water treatment for drip irrigation of agricultural land Scientific J. of the Russian Research Institute of Melioration Problems 3(35) 1-17