Modernization of structural elements of a hydrocyclone to improve the efficiency of irrigation water treatment

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

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

E-mail: masha2008-1988@mail.ru

Abstract. There are many methods of water treatment and wastewater treatment, this includes sorption filters with different loads, the use of reagents, but mechanical cleaning filters carry a heavy load. The correct selection of equipment assumes effective water purification and high-quality irrigation of crops. The article presents the results of modernization of structural elements of a hydrocyclone to improve the efficiency of irrigation water treatment. The modernization consists in the fact that an impeller with a bearing was additionally installed on the outlet of the clarified product, which increases the centrifugal force of the swirling liquid flow, thereby increasing the efficiency of cleaning irrigation water. After the cleaning process, a chemical analysis of the irrigation water was carried out, which showed that the proposed design of a hydrocyclone with an impeller effectively reduces the concentration of impurities in the irrigation water. The amount of impurities in the purified water decreased due to, increasing the centrifugal force of the swirling fluid flow, suspended solids decreased by 3 times, turbidity by 2.5 times, color by more than 29%.

1. Introduction
Cultivation of agricultural crops is not possible without high-quality irrigation, especially in arid places where there is little rain [1, 2, 3, 4]. However, water for irrigation needs can come from any water source with a different composition of chemical elements. When irrigating large areas, surface water sources are mainly used [5, 6], that is, canals, lakes, as it is economically profitable. This water is considered the most polluted and therefore must be mechanically cleaned from coarse impurities. If you do not carry out preliminary cleaning, then the pump and other equipment will break down. The process of water treatment consists in the fact that water is purified from coarse and fine particles, as well as metal-containing [7, 8, 9] elements of various types of salts, which at one time have properties to accumulate in irrigation systems.

There are many methods of water treatment and wastewater treatment [10, 11, 12], these include sorption filters with different loads [13, 14, 15, 16, 17], the use of reagents, but mechanical cleaning filters carry a heavy load. The correct selection of equipment assumes effective water purification and high-quality irrigation of crops [18-23].
2. Materials and methods

For the study, the design of the hydrocyclone was modernized (Figure 1). The hydrocyclone consists of a body that includes mating cylindrical and conical shells, a tangential inlet for supplying the initial product, has a drain pipe for withdrawing the clarified product, equipped with a filter element with a filtering side surface, and a sand pipe for withdrawing a heavy product, it is equipped with a cylindrical sorption filter, the lower edge of which is at the level of the upper edge of the tangential inlet, installed coaxially with a drain pipe on a disk that forms an additional upper chamber in the cylindrical shell for collecting the clarified product with an additional drain pipe for its output [20].

![Diagram of the hydrocyclone](image)

**Figure 1.** Hydrocyclone: 1 - Cylindrical shell, 2 - conical shell, 3 - tangential inlet, 4 - drain pipe, 5 - filter element, 6 - sand pipe, 7 - cylindrical sorption filter, 8 - disk, 9 - additional chamber for collecting the clarified product, 10 - additional drain pipe for the output of the clarified product.

The disadvantage of the above-described hydrocyclone design is a decrease in the kinetic energy inside the flow, due to the resistance arising from the collision of the flow with the wall located perpendicular to the axis of the cylinder, as a result of which the quality indicators of irrigation water are reduced.

The modernization consists in the fact that an impeller with a bearing was additionally installed on the outlet of the clarified product, which increases the centrifugal force of the swirling fluid flow, thereby increasing the efficiency of cleaning irrigation water (Figure 2).
3. Results and discussion

The principle of operation of the hydrocyclone is that the initial product, not clarified irrigation water, enters through the tangential inlet into the opposite wall of the upper shell of the hydrocyclone body hitting the impeller fixed on the outlet of the clarified product. Due to which the water flow swirls without significant losses of kinetic energy inside the flow, while increasing the centrifugal force, the heavy product hits the walls of the body, goes down along the conical shell and is discharged through the sand pipe to remove the heavy product. At the end of the cleaning process, an analysis of the irrigation water was carried out, the results of which are shown in Table 1.

Table 1. Results of chemical analysis of treated irrigation water.

| No. | Impurities, mg/l | Initial water, mg/l | Purified water, mg/l | The results of the analysis of the above described construction Figure 1 | State Standard GOST 2874-82 |
|-----|------------------|---------------------|----------------------|-------------------------------------------------|-----------------------------|
| 1   | Suspended substances | 14.3                | 3.7                  | 4.1                                              | -                           |
| 2   | Turbidity of water, EMF | 9.5                 | 2.73                 | 3.4                                              | 2.6-3.5                     |
| 3   | Color, hail.      | 31.5                | 21.2                 | 22.0                                             | 20.0-35.0                   |
| 4   | Fe(OH)₂           | 0.65                | 0.212                | 0.286                                            | 0.3                         |
| 5   | Fe₂O₃             | 0.251               | 0.115                | 0.125                                            | 0.3                         |
According to the analysis results, it can be seen that the proposed design of a hydrocyclone with an impeller effectively reduces the concentration of impurities in the irrigation water than the above-described Figure 1. The amount of impurities in the treated water decreased due to, increasing the centrifugal force while reducing the loss of kinetic energy inside the fluid flow, which makes it possible to reduce suspended solids by 3 times, turbidity by 2.5 times, color more than 29%.

4. Conclusion

Thus, using the proposed hydrocyclone design, effective cleaning of irrigation water from coarse impurities is achieved by increasing the centrifugal force while reducing the loss of kinetic energy inside the fluid flow.

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] Kruzhilin I P, Ovchinnikov A S, Kuznetsova N V, Kozinskaya O V, Fomin S D, Bocharnikov V S and Vorontsova E S 2018 Water pressure monitoring in irrigation piping as quality management tools of sprinkler irrigation ARPN J. of Engineering and Applied Sciences 13 4181-4184
[3] 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
[4] Yurchenko I. F. 2020 Development of innovative management systems for agricultural production on reclaimed lands Business. Education. Right 1(50) 42-49
[5] Rybalova O, Artemiev S, Sarapina M, Tsybulat A, Shetopalo 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
[6] 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
[7] 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
[8] 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 279(8-9) 17-24
[9] 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
[10] Kolesnikov V A, Il'in V I, Kapustin Y I, Varaksin S O, Kisilenko P N and Kokarev G A 2007 Floation Wastewater Treatment of Industrial Enterprises (Moscow: Khimiya)
[11] 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)
[12] Ksenofontov B S 2013 Intensification of wastewater treatment of engineering industries using ion flotation Sanitary Engineering 5 30-33
[13] Matsak A and Tsytlshvili K 2018 Using different filter media of stormwater treatment performance Norwegian J. of Development of the Int. Science 1(20) 19-22
[14] Kazeminejadfard F and Hojjati M R 2019 Preparation of superabsorbent composite based on acrylic acid-hydroxypropylidistarch phosphate and clinoptilolite for agricultural applications J. of Applied Polymer Science 136(16) 4736

[15] Bochkarev G R and Pushkareva G I 1988 On a new natural sorbent for the extraction of metals from aqueous media Physical and Technical Problems of Mining 4 46-51

[16] Ovchinnikov A S, Bocharnikov V S and Denisova M A 2019 Technology of wastewater treatment of poultry enterprises using natural sorbents with the addition of ferrite suspension Proc. of the Nizhnevолжsky Agrouniversity Complex: Science and Higher Professional Education 1(1) 15-22

[17] 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 Nizhnevолжsky Agrouniversity Complex: Science and Higher Professional Education 1(57) 260-267

[18] 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

[19] 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

[20] Lamskova M I, Filimonov M I and Novikov A E 2016 The use of swirling flows and sorption effects in water treatment in low-pressure irrigation systems with local supply Scientific J. of the Russian Research Institute of Melioration Problems 4(24) 189-201

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

[22] Kruzhilin I P, Ganiev M A, Kuznetsova N V and Rodin K A 2018 Dynamics of total water consumption and yield of periodically moistened rice during sprinkling and drip irrigation in the Volgograd region Proc. of the Nizhnevолжsky Agrouniversity Complex: Science and Higher Professional Education 3(51) 34-42

[23] Kuznetsova N V, Kuznetsov Yu V, Kozinskaya O V and Denisova M A 2020 Influence of hydraulic parameters on irrigation quality Proc. of the Nizhnevолжsky Agrouniversity Complex: Science and Higher Professional Education 2(58) 73-83