Water filter with central perforated pipe for livestock complexes

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Abstract. Improving the livestock sector is a priority for the development of agricultural production in the Russian Federation. The development of animal husbandry to a certain extent depends on the use of clean drinking water. The use of contaminated drinking water for animals and birds leads to the accumulation of harmful and toxic substances in meat, milk and eggs. The use of such products by people significantly affects their health, leads to various diseases and shortens life expectancy. To filter water from various impurities, slotted filters are used in livestock complexes that do not provide high-quality water purification. A prototype of a filter for water purification with a central perforated pipe with a productivity of 5 m³/h with an increased service life of the filter bag has been developed. The developed filter provides water purification from high concentration of salts of iron, manganese, chlorine, hardness salts, hydrogen sulfide, pesticides, and also various organic compounds. The purified water is clean and transparent, has a pleasant taste, contains the optimal chemical composition of various impurities, does not contain pathogens and helminth eggs, and therefore meets the high sanitary and hygienic requirements for the safe drinking water for farm animals in the water treatment line of the livestock complex. It can also be used in chemical water treatment units of thermal power plants and other organizations.

1. Introduction

One of the main tasks of the development of the agriculture industry of Russia today is to improve the livestock sector, which will strengthen the food independence of the country and its economy as a whole. However, over the past 10 years, there has been a decrease in the number of cows by 44%, one of the main reasons for which is the lack of effective water treatment systems [1, 2, 3].

The quality of drinking water is one of the most serious risk factors in modern livestock and poultry farming. Up to 60 ... 70% of the body of animals and birds is water. Water serves as a solvent, provides the exchange and transport of nutrients, and helps to remove toxic products. For animals and birds, the need for water is twice as much as for feed. Thus, water is an indispensable element for the normal functioning of animals. The most complete and economical treatment of water from various contaminants according to the requirements of regulatory documents is one of the most urgent tasks in the development of animal husbandry [4, 5, 6, 7, 8, 9, 10].

Nowadays, one of the main methods of water purification from these pollution in water treatment systems in animal husbandry is filtration through filters loaded with highly efficient materials: fibrous...
ion-exchange material (FION), carbon fiber sorbents (CFS) and activated carbon tissue (ACT) [11, 12, 13].

The filters with these materials have a number of technological and design disadvantages: they do not provide an even distribution of the flow rate in the filter material, have low productivity, require great efforts to create the necessary density of the loading material, have a large mass and dimensions, do not combine three technological operations in one filter (mechanical, ion-exchange and sorption purification), have a large pressure loss of the filtered fluid, as well as uneven contamination of the filter material makes it difficult to wash the filter [14, 15, 16].

In this regard, the development of new technologies and new filter designs is relevant.

2. Materials and methods
Based on experimental studies of filters for water purification using the method of electrohydrodynamic analogies [17], a prototype filter for water purification with a central perforated pipe with a productivity of 5 m$^3$/h was developed and manufactured, the general view and technological scheme of which are shown in Figure 1 [18].

![Figure 1. General view (a) and scheme (b) of a filter prototype for water purification with a central perforated pipe: 1 - pipe for supplying the liquid being cleaned; 2 - purified liquid outlet pipe; 3 - layer (in the form of a ring) made of CFS material; 4 - central outlet pipe with perforation; 5 - pressing device; 6 - outlet section; 7 – inlet section; - liquid flow direction.]

The main structural and technological indicators of the developed filter for water purification with a central perforated pipe are given in Table 1.

| Name of indicator and unit of measurement                  | Value          |
|-----------------------------------------------------------|----------------|
| Throughput, m$^3$/h                                       | 5.0            |
| Working pressure, MPa                                      | 1.6            |
| Minimum size of the detained filtered particles, microns   | 0.0005-0.0018  |
| Outer diameter of the load, m                             | 0.32           |
| Inner diameter of the filter, m                           | 0.30           |
| Inner diameter of the inlet pipe, m                       | 0.0271         |
| Inner diameter of the outlet pipe, m                       | 0.0271         |
| Height of the filter element, m                           | 0.6            |
Filter height, m 0.64
Outer diameter of the filter, m 0.328
Inner diameter of the central perforated tube, m 0.052
Outer diameter of the central perforated pipe, m 0.057
Diameters of the holes of the central perforated pipe, m 0.003

A prototype filter for water purification with a central perforated pipe contains a pipe for supplying a liquid being cleaned 1, a central outlet pipe with perforation 4, a layer (in the form of a ring) 3 made of CFS material, a pressing device 5, a purified liquid outlet pipe 2, an inlet section 7, an outlet section 6.

When performing the technological process with the developed filter, water is supplied to the pipe 1, from which it subsequently enters the inlet section 7 and is filtered through layers (in the form of a ring) 3 made of CFS material. Next, the purified water passes into the central outlet pipe 4 with perforation and enters the outlet section 6. From the outlet section 6, water through the outlet pipe 2 of the purified liquid is piped to the water tower.

Distinctive features of the developed prototype filter for water purification with a central perforated pipe in comparison with the closest analogues are as follows.

The manufacture of a central pipe with holes, the number of which increases along the length of the pipe from the bottom to the top, determines that the hydraulic resistance will be greater when a stream of water is passing through the lower part of the pipe than when a stream is passing through its upper part, since the area of the water flow section at the bottom is less. Therefore, in this filter with a lower admission and discharge of water, due to the hydraulic resistance created by the perforation of the central pipe, the water flow rate will be uniform along the height of the filter bag (load). As a result of the uniform distribution of the liquid being cleaned over the loading height, the surface of the filter bag will evenly absorb various contaminants over the entire area, providing for high-quality water purification. This circumstance also increases the period of use of the filter bag.

Perforation of the central pipe with round holes of the same diameter determines the manufacturability, which does not require the use of complex equipment.

Tests of the prototype filter for water purification were carried out according to Russian State Standard GOST 50554-93 “Industrial cleanliness. Filters and filter elements. Test methods” [19] at the livestock complex of the Agrofirm “Trud” agricultural enterprise of the Kungursky District of the Perm Krai in the period from 2014 to 2015.

A prototype filter for water purification with a central perforated pipe was installed in the water supply system of the livestock complex. The water supply scheme for the livestock complex is shown in Figure 2, and the general view of the loose housing unit for cows of the livestock complex with the drinking system is shown in Figure 3.

![Figure 2. Scheme of water supply for the livestock complex: 1 - submersible pump in a well; 2 - prototype filter with a central perforated pipe for water purification; 3 - water tower; 4 - main pipeline; 5 - loose housing unit for cows of the livestock complex; 6 - drinking system for cows; 7 - supply pipelines in the drinking system for cows; 8 - dosing valves for supplying water to drinking bowls; 9 - drinking bowls.](image-url)
Figure 3. General view of the loose housing unit for cows of the livestock complex with a drinking system.

The technological line of water supply consists of a submersible pump 1 in a well, a prototype filter with a central perforated pipe for water purification 2, a water tower 3, and a pipeline 4. In the loose housing unit 5 for cows of the livestock complex, the drinking system for cows 6 was installed, including supply pipelines 7, dosing valves 8 for supplying water to drinking bowls 9.

The technological process of the water supply line of the livestock complex proceeds as follows.

Water is pumped from a well by a submersible pump 1 through a pipeline to a water tower 3 through a prototype filter with a central perforated pipe 2. In a prototype filter 2, water is purified from various impurities and contaminants. From the water tower 3, water purified from impurities and contaminants through the main pipeline 4 enters the drinking system for cows 6. In the drinking system for cows 6, the water through the supply pipelines 7 enters the drinking bowls 9. The dosed water supply to the drinking bowls 9 is made through the valves 8. For the provision of drinking water to animals at low temperatures (in winter), the drinking bowls 9 are equipped with water heating devices.

To determine the flow rate of water through a prototype filter with a central perforated pipe installed in the water supply line of the livestock complex (Figure 2), a VT-50G Meter turbine flange water meter is used [20].

This meter is installed on the pipeline going from the discharge tube of the purified liquid. Time is noted using a stopwatch. The volume of water that has passed through the filter during the time measured by the stopwatch is determined according to the meter reading. The flow through the filter is determined by dividing the liquid volume by the measured time.

To determine the quality of water before and after the filter, samples are taken through couplings with valves located on the pipelines for inlet and outlet of liquids from the filter. Samples were taken in 5 liter plastic probes in triplicate.

To determine the pressure loss in the filter, the excessive pressure is measured before and after the filter using pressure gauges. The value of pressure loss is found by subtracting the pressure value after the filter from the pressure value before the filter.

When testing a prototype filter with a central perforated pipe, the analysis of the taken samples of water coming from the water intake and after its purification with the developed filter was carried out in the laboratory of Rodnik LLC, Perm.

3. Results and Discussion
To analyze the quality of the water entering the water treatment line of the livestock complex from the well, sampling was carried out through a coupling with a valve located on the outlet pipeline of the
prototype filter. The indicators of the composition of the purified water coming from the water intake of the livestock complex of the Agrofirm “Trud” agricultural enterprise in the Kungursky District of the Perm Krai are shown in Table 2.

As a result of the analysis of water samples in the laboratory of Rodnik LLC in Perm, it was established that the total hardness is 30.0 mg-equiv/L. This indicator exceeds MAC according to the standard by 4.29 times. Raw water is hard, characterized by the presence of bicarbonate salts of calcium Ca(HCO₃)₂ and magnesium Mg(HCO₃)₂.

Table 2. The indicators of the composition of the purified water coming from the water intake of the livestock complex of the Agrofirm “Trud” agricultural enterprise in the Kungursky District of the Perm Krai.

| Indicator          | Total hardness, mg-equiv/L | Pesticides (butyphos), mg/l | Hydrogen sulfide, mg/l |
|--------------------|---------------------------|-----------------------------|-----------------------|
|                    | 30.0                      | 0.25                        | 0.01                  |

| Indicator | Oil products, mg/l | Total mineralization (dry residue), mg/l | Iron (Fe, total), mg/l |
|-----------|-------------------|------------------------------------------|-----------------------|
|           | 2.6               | 2000                                     | 0.6                   |

| Indicator | Turbidity, mg/l (by kaolin) | Off-flavour, points |
|-----------|-----------------------------|--------------------|
|           | 5.0                         | 3                  |

| Indicator | Odor, points | Color, degrees | Heavy metals (lead (Pb, total)), mg/l |
|-----------|--------------|---------------|--------------------------------------|
|           | 3            | 30            | 0.1                                  |

The mineralization degree of water, i.e. the total content of substances dissolved in it, was 2000 mg/l, which is also 1.0 times more than the standard for MAC.

Odor intensity and taste of water, evaluated by a five-point system, were: noticeable odor and taste - 3, due to the content of various impurities. Moreover, according to the quality standards for drinking water, its odor and taste should not be higher than 2 points.

The turbidity of water from the intake of the livestock complex was 5.0 mg/l, which, according to standard for MAC, should not exceed 1.5 mg/l. The color of water at the farm was 30°, which should be no more than 20° by quality standards. These indicators are caused by the presence of dissolved mineral, organic, and humic substances in raw water.

Raw water also has a high content of pesticides, iron, sulfur, and oil products. The content of pesticides in water is 0.25 mg/l, iron is 0.6 mg/l, hydrogen sulfide is 0.01 mg/l, and oil products are 2.6 mg/l. These indicators exceed the standard for MAC for pesticides 766.7 times, for iron - 2.0 times, for hydrogen sulfide - 3.3 times, for oil products - 26.0 times. The high content of pesticides and oil products in the water of the water source of the livestock complex is associated with runoff from fields treated with pesticides to protect plants from various pests, as well as the ingress of diesel fuel, oil and other components of oil products into the soil due to careless use in workshops of an agricultural enterprise.

Thus, the water entering the water treatment line of the livestock complex from the well does not meet sanitary and hygienic requirements and is not safe for farm animals. In accordance with this, it is necessary to purify raw water with filters that ensure compliance with the sanitary and hygienic conditions of drinking water for farm animals.

To analyze the quality of water entering the water treatment line of the livestock complex after cleaning from various impurities, sampling was carried out through a coupling with a valve located on the outlet pipeline of the prototype filter. The indicators of the composition of the quality of water treatment with the developed prototype filter are shown in Table 3.
Table 3. The indicators of the composition of the quality of water treatment with the developed prototype filter.

| Indicator | Total hardness, mg-equ/L | Pesticides (butyphos), mg/l | Hydrogen sulfide, mg/l |
|-----------|--------------------------|-----------------------------|-----------------------|
| After filter | Standard for MAC | After filter | Standard for MAC | After filter | Standard for MAC |
| 3.0       | 7.0                     | 0.0003                     | 0.0003                | 0.0025       | 0.003           |

| Indicator | Oil products, mg/l | Total mineralization (dry residue), mg/l | Iron (Fe, total), mg/l |
|-----------|-------------------|----------------------------------------|-----------------------|
| After filter | Standard for MAC | After filter | Standard for MAC | After filter | Standard for MAC |
| 0.0022     | 0.1               | 200                      | 1000                  | 0.25        | 0.3             |

| Indicator | Turbidity, mg/l (by kaolin) | Off-flavour, points |
|-----------|-----------------------------|-------------------|
| After filter | Standard for MAC | After filter | Standard for MAC |
| 0.3        | 1.5                        | 1                 | 2                 |

| Indicator | Odor, points | Color, degrees | Heavy metals (lead (Pb, total)), mg/l |
|-----------|--------------|----------------|--------------------------------------|
| After filter | Standard for MAC | After filter | Standard for MAC | After filter | Standard for MAC |
| 1          | 2             | 15            | 20                     | 0.01        | 0.03            |

The physical properties of water, specifically transparency and turbidity, color, odor and taste, have significantly improved after cleaning with a prototype filter. Odor intensity and taste of water, evaluated by a five-point system, amounted to 1 point - very weak, which is lower than the standard for MAC, which should not be higher than 2 points.

The turbidity index was 0.3 mg/l and improved 5 times in comparison with the standard for MAC. The color of drinking water for animals on the farm became 15°, which is 1.3 times higher in comparison with sanitary and hygienic requirements. Drinking water became transparent due to the fact that organic or mineral particles, as well as dissolved humic substances, were purified from raw water with the prototype filter.

The filter element of the prototype filter reduced the high content of pesticides, iron, hydrogen sulfide and oil products in raw water. The content of pesticides in the water after its purification is 0.0003 mg/l, iron - 0.25 mg/l, hydrogen sulfide - 0.0025 mg/l, oil products - 0.0022 mg/l. These indicators do not exceed the standard for MAC for pesticides, for iron and hydrogen sulfide - 1.2 times lower, for oil products - 45.5 times lower. The presence of heavy metals (lead) in purified water also decreased to 0.01 mg/l, which is 3 times less than the standards for MAC.

As a result of separating various impurities from raw water by the filter element of the prototype, its total hardness was 3.0 mg-equ/L. According to the standard for MAC, this indicator is 2.3 times lower.

The degree of mineralization of filtered water, i.e. the total content of substances dissolved in it, has a value of 200 mg/l, which is also 5.0 times less than the standard for MAC.

4. Conclusion

Thus, the advantage of the developed prototype filter in comparison with analogs is, due to its constructive implementation, the improvement of the quality of water purification for domestic needs and drinking water for the population and farm animals from various contaminants, and an increased service life of the filter bag. The developed filter provides water purification from high content of salts of iron, manganese, chlorine, hardness salts, hydrogen sulfide, pesticides, as well as various organic
compounds. Purified water is clean and transparent, has a pleasant taste, contains the optimal chemical composition of various impurities, does not contain pathogens and helminth eggs, and therefore meets the high sanitary and hygienic requirements for the safe drinking water for farm animals in the water treatment line of the animal husbandry complex. It can also be used in chemical water treatment units of thermal power plants and other organizations.

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