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Improvement Of The Technology And Technical Means For Cleaning Closed Horizontal Drainage Systems From Sediments In Irrigated Lands

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Abstract: This article analyzes the methods and technical means of cleaning the closed horizontal drainage system from sediments in irrigated lands. Closed horizontal drainage cleaning devices are classified according to the type, shape of the working head and structural features. The use of the recommended closed horizontal drainage cleaning head in drainage cleaning allows reducing manual labor, water consumption, fuel and labor costs in cleaning closed horizontal drainage from sediments.

Keywords: Drainage, nozzle, drainage cleaning machine, irrigation lands.

Introduction: Closed horizontal drainage systems play a crucial role in irrigated agriculture by managing excess groundwater and salts to maintain soil fertility [1]. These systems, which typically involve perforated pipes buried 1-3 meters deep, are prone to sediment buildup, reducing their efficiency and requiring periodic cleaning [2]. This comprehensive survey examines the evolution of technologies and techniques for improving sediment removal, drawing on historical developments, current challenges, and recent innovations [3]. It included prevention strategies, cleaning methods, and supporting information to provide complete information to agricultural engineering practitioners [4].

The territory of the republic Uzbekistan has unique soil and climatic conditions, as a result of insufficient natural drainage and high mineralization of groundwater, a number of areas are "primarily saline" [5]. At the same time, as a result of irrational use of water resources and the negative impact of other anthropogenic factors, "secondary salinization" of lands is observed in some regions, with varying degrees of salinity observed on 45.7% of the area of irrigated land [6].

The water management of the Republic of Uzbekistan is a complex complex of irrigation systems serving about 4.3 million hectares of irrigated land [7], including more than 180 thousand kilometers of canal networks and 106,507 thousand kilometers of collector-drainage networks [8]. The total length of closed horizontal drainage is more than 36,913 thousand km, of which about 14,6 thousand km (39.5%) require immediate and subsequent periodic flushing, and about 3,9 thousand km are in poor condition [9]. A significant part of the arable land, and almost all of it, is irrigated land for technical crops, which is served by a powerful state irrigation system [10].

METHOD

The research was conducted to analyze, classify, and improve the existing technologies and technical means for cleaning closed horizontal drainage systems from sediments in irrigated lands. The study included a combination of theoretical analysis, field observation, and laboratory-based evaluation of hydraulic and mechanical parameters. The main focus was on identifying the limitations of current cleaning mechanisms and the causes of sediment accumulation in closed horizontal drainage systems. The collected data were analyzed to determine the relationship between sediment thickness, hydraulic resistance, and flow efficiency within drainage pipes. Existing drainage cleaning devices were classified according to their: Type of mechanism (hydrodynamic, hydromechanical, or combined), Shape and configuration of the working head, structural and operational features affecting performance and efficiency.

This classification formed the basis for identifying design improvements and optimizing the working parameters of the cleaning system. Based on the analysis, a new design concept for a jet-forming cleaning head was proposed. The improved head was developed to ensure efficient sediment removal depending on the degree of silting and to increase the reactive thrust force for forward motion within the pipeline Key parameters such as water pressure, nozzle diameter, hose length, and flow rate were optimized through theoretical calculations and experimental verification.

RESULTS AND DISCUSSION

Given the above technical condition of the operated structures and types of drainage, it is practically impossible to objectively assess their effectiveness by the total volume of the collector-drainage flow. Judging by the data of operational organizations, with a steady increase in areas with medium and strong soil salinity in time and space (2022), the volume of collector-drainage flow in the context of areas located along the trunk of the main watercourses ranges from 28–31% (Navoi, Jizzakh) to 76.6–80.6% (Namangan, Khorezm) of specific water supply per unit of irrigated area. Apparently, a wide range of runoff changes is due to their formation and due to the inflow of surface waters that form in the mountainous, foothill zone and the discharge of irrigation waters in the plain part into the existing CHD (Table 1).

Table 1. The ratio of water supply and collector-drainage runoff in the irrigated zone

Areas	Medium and highly saline lands, in % of the surveyed area			2022 year			
	1970	**1992**	**2016**	Irrigated area, thousand ha	Specific water supply, thousand м^3/ha	Drainage runoff, м^{3}thous./ha	in % of water supply
River basin Syrdarya							
Andijan	13.0	0.9	25.1	265.0	20.0	10.5	51.4
Namangan	7.4	3.2	30.0	283.0	12.0	9.2	76.6
Ferghana	22.0	12.0	27.0	360.0	19.0	12.0	63.0
Syrdarya	26.0	22.0	40.0	287.0	13.0	7.5	58.0
Jizzakh		18.4	36.0	300.0	12.0	4.0	31.0
River basin Amu Darya							
Surkhandarya	9.0	15.0	17.0	326.0	12.4	3.5	28.2
Bukhara	26.2	32.4	32.0	274.0	17.0	10.0	56.0
Kashkadarya	5.4	18.5	16.0	515.0	9.5	3.4	35.7
Navoi		33.6	30.0	118.0	10.3	2.9	28.1
Samarkand	1.8	1.0	9.5	379.7	9.8	6.6	67.3
Republic of Karakalpakstan	38.5	52.2	60.5	510.6	13.9	5.0	35.9
Khorezm	22.4	23.0	34.3	265.6	14.5	11.7	80.6

Figure 1. Drainage washing machine based on the Krantas and PDT-200

Various cleaning devices identified during the literature review were deployed on-site. These included mechanical auger-based cleaners, water jet systems, robotic cleaners, and chemical flushing devices. The drain flushing set PDT-200 is a complex of units of two tractors of class 10 kN (TTZ-100) and includes the main pumping station on a single-axle trailer with a drum, an auxiliary pumping station and a tank on a wheeled tractor. In Uzbekistan, at the KRANTAS LLC enterprise, joint production of a new sewer washing machine KPM6-01 on the KAMAZ 43118 chassis with a water reserve of 6000 liters and a hose length of 200 pm was organized (Picture 1). Each device was tested in different parts of the drainage system to determine its performance across a range of conditions: Auger-based systems were deployed in areas with heavy sediment buildup, testing their ability to physically dislodge and remove obstructions from the pipes. High-pressure water jet devices were used to assess their effectiveness in clearing loose debris and sediment. Automated robotic devices, where applicable, were tested in more modern systems to evaluate their efficiency in performing routine cleaning tasks with minimal human intervention (Figure 1).

Figure 2. Drainage cleaning process

After field testing, feedback was gathered from stakeholders involved in the testing process, including drainage system operators, local maintenance teams, and engineers. These stakeholders provided insights into the practical aspects of using each cleaning device, including user-friendliness, training requirements, and long-term reliability. Feedback from stakeholders was crucial in understanding the operational challenges and the potential for scaling the use of certain devices in different regions. By conducting field tests and analyzing relevant case studies, this method provided a comprehensive understanding of the practical applications, benefits, and limitations of various cleaning devices for closed horizontal drainage systems. The results from this phase of the research helped identify the most effective technologies for cleaning drainage pipes and offered valuable insights for improving maintenance practices and system sustainability.

Device for cleaning closed horizontal drainage

One of the main working components of the drainage cleaning machine is its working head (nozzle). The structural efficiency and the accuracy of calculating its main parameters determine the overall economic performance of the machine. In general, the working head must ensure uniform cleaning of the inner surface of the drainage pipe and the removal of sediment deposits formed inside it.

According to its functional purpose, the working head is divided into the following main types of hydrodynamic washing nozzles: Pass-through (continuous flow) nozzles, Reversible nozzles, and Rotary (rotational) nozzles.

Pass-through nozzles are the simplest and most reliable, which is why they are the most commonly used in drainage pipe cleaning. Typically, they have one front and several rear water jet outlets. The total reactive force of the front jets is smaller than that of the rear ones. Under the action of the reactive thrust produced by the rear water jets, the nozzle moves along the pipe, washing away the sediments and simultaneously pulling the hose behind it. The removal of the washed-out sediments from the pipe occurs mainly under the influence of the highly turbulent water flow generated by the rear jets, which is directed along the cleaning hose.

Reversible nozzles are efficient devices designed to remove and eliminate significant blockages and deposits in pipelines by remotely switching between rear, front, and lateral jets at the clogging point. These nozzles are quite versatile and are mainly used for cleaning pipelines with rear-directed water jets. However, due to their complex construction, reversible nozzles are mostly used in municipal utility systems and have not been applied in reclamation drainage cleaning machines.

Rotary nozzles, in addition to traditional rear jets, have lateral washing jets that rotate at high speed due to the reactive force of the rotor as the nozzle moves along the pipe. As a result, the lateral jets evenly clean the inner surface of the pipe.

For removing large sediment accumulations and plant roots inside pipes, more complex nozzles equipped with hydromechanical working elements are used. These devices combine the washing process with milling (cutting) action, and therefore, this method of cleaning is referred to as the hydromechanical cleaning method. It is characterized by the simultaneous effect of pressurized water jets and various types of mechanical loosening tools. Typically, the hydromechanical method requires high static water pressure and smooth internal pipe surfaces, which is why it is primarily applied in municipal drainage systems. The hydraulic cleaning method, in turn, is conditionally defined as the process of cleaning or washing the pipeline using a water (liquid) flow that passes directly through the pipe being cleaned (figure 3).

This method can be implemented in several ways when cleaning drainage pipes: by periodically blocking the drainage pipeline when there is an existing drainage flow, by pumping out drainage water when the groundwater level is high, by injecting water into the drainage network and allowing it to flow out naturally, by supplying water into the drainage network and then removing it with a pump.

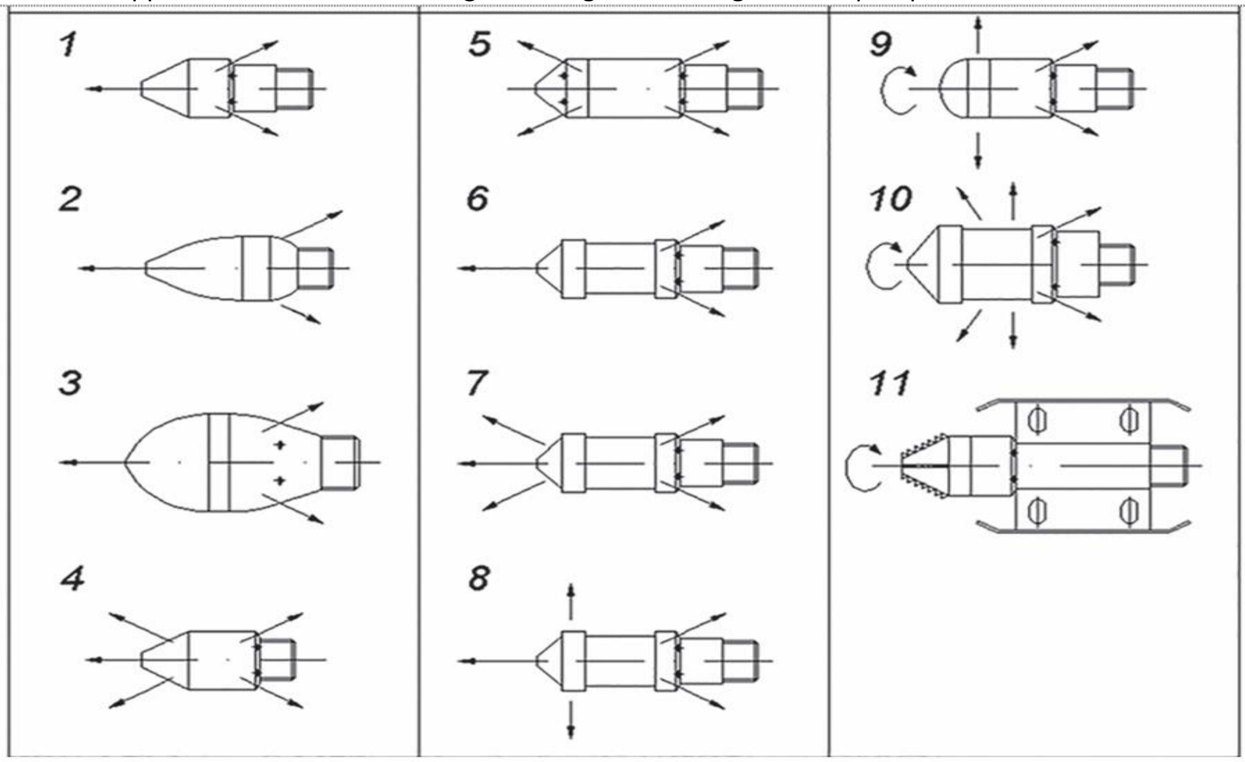

Figure 3. Schemes of nozzles used in drain cleaning machines

The study highlighted that mechanical devices and water jet systems were the most efficient at clearing blockages in closed horizontal drainage systems, with water jet systems being faster and more effective for lighter blockages. The results underscore the importance of choosing the right cleaning device based on the specific needs of the drainage system, with a combination of methods being the most effective approach for maintaining closed horizontal drainage systems.

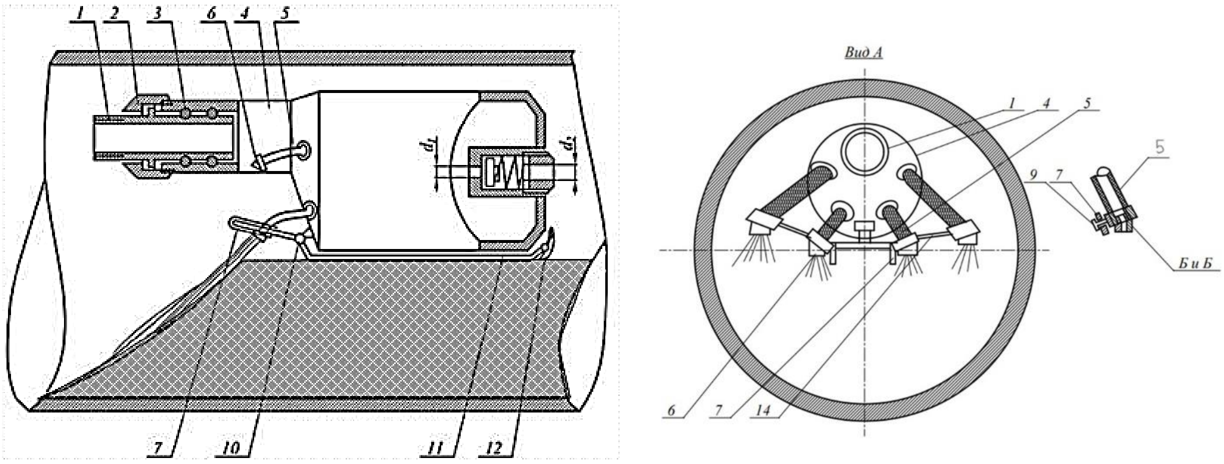

Figure 4. Schematic diagram of the location of the washing head with a lick inside a clean drain pipe and location of jet forming nozzles

In certain sections of the pipeline being cleaned, the thickness of the sediment deposits is equal to zero, the levers 7 open completely and the flexible rubber-fabric hoses 5 of the jet-forming nozzle 6 take a horizontal position (in this case) the reactive force of the working agent is completely (100%) spent on driving the device forward. Before operation, the device for cleaning pipelines from sediment deposits is inserted into the pipeline and pushed to the available length, water supplied by the pump through the water supply hose through the branch pipe 1, through the housing 4, and through the rubber-fabric hose 5 enters the jet-forming nozzle 6, washes away sediment deposits and develops a reactive force (Figure 4).

CONCLUSIONS

Due to the water shortage observed in recent years, the poor state of land reclamation, and the lack of timely implementation of other organizational measures, the level of water supply of several thousand hectares of irrigated land remains low, and the land area of irrigated Maintaining the reclamation state of irrigated lands in an optimal state is an integral part of the state policy to improve the welfare of the population and an essential factor in the development of agriculture land is falling from circulation every year. Most probably, the main reasons for this research discontinuity lie in the short-period funding of research projects and thus a lack of long-term, continuing studies and of sustainable integration of irrigation and drainage research into agricultural and wastewater management concepts.

A key innovation introduced in this study is the improved schematic diagram for the washing head and the placement of jet-forming nozzles inside the drain pipe. The new schematic design enhances the precision of water jet cleaning by optimizing the location of the jet nozzles, ensuring better coverage and higher cleaning efficiency. This design improvement helps in effectively removing debris from the pipes while minimizing water consumption and damage to the drainage infrastructure. According to the results of the tests, the machine for cleaning a closed horizontal drain equipped with an improved washing head has a working capacity of 35-40 m/h, a water consumption of 45-50 liters per meter of drain, and a washing distance of 100-200 m per side, which allows increasing the working capacity by 15-20 percent, reducing water consumption by 20-25 percent, and reducing energy consumption by up to 1.2 times.

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