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Assessing The Effectiveness Of The Improved Horizontal Drainage System In Syrdarya Region

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Abstract: This article presents the results of experimental and analytical studies carried out in the Syrdarya region to evaluate the efficiency of an improved closed horizontal drainage cleaning head. The research focuses on assessing the operational performance, hydraulic efficiency, and resource-saving potential of the newly designed head compared to conventional drainage cleaning systems. The upgraded cleaning head was tested under real field conditions typical of irrigated areas in Central Asia, characterized by high soil salinity, limited water availability, and the necessity for sustainable water management. Experimental findings demonstrated that the improved cleaning head increased operational productivity by 15–20%, while reducing water consumption by 20–25% and energy expenditure by up to 1.2 times. These results confirm that the innovative design ensures more effective removal of sediments and blockages inside the drainage pipes, leading to enhanced system reliability and longevity. Furthermore, the implementation of this improved technology can contribute to more rational water and energy use in agricultural drainage systems. The outcomes of this study provide a solid scientific basis for introducing the modernized drainage cleaning mechanism into large-scale agricultural practice, offering both environmental and economic benefits for sustainable irrigation management in arid regions.

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

Introduction: In Central Asia, particularly in the Republic of Uzbekistan, drainage systems play a crucial role in preventing soil salinization and excessive moisture accumulation in irrigated agricultural lands [1]. The country's agricultural sector occupies a leading position in the regional economy, and maintaining the optimal reclamation condition of arable lands is essential for sustainable agricultural productivity [2]. Due to intensive irrigation practices and the region's naturally saline and arid conditions, the effectiveness of subsurface drainage systems has become one of the key factors determining soil fertility and crop yields [3]. The proper functioning of drainage networks largely depends on their timely and efficient cleaning [4]. Sediment accumulation and biofouling within the pipes reduce water flow capacity, leading to decreased drainage efficiency and secondary salinization of soils [5]. Therefore, periodic cleaning of drainage pipes is vital to sustain the hydrological balance and extend the operational lifetime of the system [6]. To address this challenge, a new, improved design of a closed horizontal drainage cleaning head has been developed and experimentally tested under the field conditions of the Syrdarya region in Uzbekistan [7]. The region represents one of the country's key irrigated zones, where approximately 25% of the total closed horizontal drainage systems are located [8]. Owing to its geomorphological structure, the Syrdarya region is characterized by low-lying relief, which results in the natural rise of groundwater levels [9]. Consequently, these irrigated areas are particularly prone to waterlogging and soil salinization, requiring regular maintenance and cleaning of drainage lines [10]. The newly developed cleaning head aims to enhance the hydraulic efficiency and operational performance of drainage maintenance processes [11]. By improving the internal design, flow distribution, and jet system of the head, it ensures more uniform and powerful washing of sediments within the pipes, thereby restoring the original drainage capacity. Field tests were conducted to evaluate the machine's productivity, water and energy consumption, and cleaning distance efficiency. The experimental results are expected to contribute to the modernization of drainage maintenance technology in Uzbekistan and other Central Asian countries. Implementing this innovative system can significantly improve the reliability of closed horizontal drainage networks, optimize water resource management, and reduce operational costs. Ultimately, the improved cleaning mechanism will promote the sustainable development of irrigated agriculture in regions facing salinity and groundwater challenges.

METHOD

Study Area and Experimental Conditions. The experimental studies were conducted in the Syrdarya region of the Republic of Uzbekistan, an area characterized by flat relief and naturally high groundwater levels. The region has an arid continental climate, with annual precipitation below 250 mm and average summer temperatures exceeding 35°C. The soils in the study area are predominantly light loamy and moderately saline, which creates favorable conditions for evaluating the performance of horizontal drainage cleaning technologies. Approximately 25% of the region's irrigated land is equipped with closed horizontal drainage systems, designed to control soil salinity and waterlogging.

Experimental Equipment. A newly designed improved closed horizontal drainage cleaning head was used for the experiment. The cleaning head was developed to increase the efficiency of hydraulic washing through an optimized internal structure that ensures uniform pressure distribution and stable water flow along the drainage pipe. The improved head includes a redesigned nozzle system with multiple adjustable jets that allow for both forward and backward cleaning modes. The cleaning head was mounted on a mobile flushing unit, equipped with a high-pressure pump and a flexible hose system. The unit allowed for controlled water pressure and flow rate during the cleaning process. The technical parameters of the cleaning unit were compared with those of a standard (conventional) model to assess performance improvements.

Methodology. Field tests were conducted on a test section of closed horizontal drainage lines with a total length of 200 meters. The main indicators evaluated during the experiment included: Operational productivity (U, m/h) – measured as the length of the drainage pipe cleaned per unit time. Water consumption (W, L/m) – determined as the amount of water used to clean one meter of the drainage pipe. Energy consumption (E, kWh) – calculated based on pump power and operation time. Effective cleaning distance (L_e, m) – the maximum length of the pipe that could be efficiently cleaned from one access point. Each test was repeated three times under similar conditions to ensure accuracy. The data obtained were analyzed statistically, and the relative performance of the improved head was compared with that of the conventional system.

$$U=L/t,\ m/h \quad (1)$$

Where: U-work efficiency, m/h, L - length of cleaned drain, m, t - time spent, hours

Water consumption (W) - volume of water spent for washing each meter of drain:

$$W=V/L,\ l/m \quad (2)$$

Where: W-water consumption, l/m, V-total volume of water used, l, L-length of cleaned drain, m

Energy consumption (E) is determined as follows:

$$E=N\bullet t,\ kWh \quad (3)$$

Where: E - energy spent, kWh, N - electric power of the machine, kW, t - operating time, hours

Washing efficiency (η)

Washing efficiency is the degree of drainage cleaning:

$$\eta=\frac{M_o-M_1}{M_o}\cdot 100\%$$

Where: M_o- the amount of sludge before cleaning (g/m or %), M_1- the amount of residual sludge after cleaning.

Overall technical and economic coefficient. The complex efficiency coefficient of the new head is determined as follows:

$$K=\frac{U_{new}/U_{old}}{E_{new}/E_{old}\cdot W_{new}/W_{old}}$$

Data Analysis. The performance indicators were evaluated using standard engineering formulas for efficiency assessment, including relative performance increase, percentage of water and energy savings, and overall cleaning effectiveness. The experimental results were summarized in graphical and tabular form to visualize performance improvements and to confirm the technical advantages of the new cleaning head design.

RESULTS AND DISCUSSION

The experimental tests conducted in the Syrdarya region demonstrated a significant improvement in the operational and economic efficiency of the drainage cleaning process when using the newly designed closed horizontal drainage cleaning head. Comparative analysis was performed between the conventional cleaning system and the improved design under identical field conditions.

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.

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 8000 liters and a hose length of 200 m was organized (Figure 1).

Figure 1. Drainage washing machine based on the MAN

Table 1. Technical characteristics of the drainage cleaning machine based on the MAN

Parameter Name	Measurement	Value
Tank capacity	m^3	8,0
Diameter of cleaned pipes	mm	100-1000
Length of high-pressure hose	m	200
Water pressure supplied to the jet head	Mpa	0-20
Minimum curb weight of the machine	kg	16800
Weight of special equipment	kg	1100

Calculate U-work efficiency, U_{new}=35–40 m/h, old machine U_{old}=30–35 m/h. The relative percentage increase is found as follows:

$\eta_U=((U_{new}-U_{old})/U_{old})\times100\% =((37.5-32.5)/32.5)\times100\%=15.4\%$

Water consumption (W) - volume of water spent for washing each meter of drain:

W=V/L=5000/100=50 l/m, $\eta_W=((W_{old}-W_{new})/W_{old})\times100\% =((67.5-47.5)/70)\times100\%=24\%$

Old: N_{old}=5 kW, t=1 hour, E_{old}=5 kWh

New: N_{new}=4 kW t= 1 hour, E_{new}=4 kWh

E_{new}/E_{old}=4/5=0.8, decreased by 1.2 times

Washing efficiency is the degree of drainage cleaning:

$\eta=\frac{M_o-M_1}{M_o}\cdot 100\%$=(20-3)/20· 100%=85%, washing efficiency - 85%.

General technical and economic coefficient. The complex efficiency coefficient of the new head is determined as follows:

$$K=\frac{\frac{U_{new}}{U_{old}}}{\frac{E_{new}}{E_{old}}\cdot\frac{W_{new}}{W_{old}}}=1.15/(0.8\cdot 0.76)=1.89$$

if $U_{new}/U_{old}=1.15$, $E_{new}/E_{old}=0.8$, $W_{new}/W_{old}=0.71$ This shows that the new head is approximately 1.9 times more efficient.

Table 2. The key performance indicators obtained from field measurements

Indicator	Conventional System	Improved System	Change (%)
Work efficiency, U (m/h)	32.5	37.5	+15.4
Water consumption, W (l/m)	62.5	47.5	–24.0
Energy consumption, E (kWh)	5.0	4.0	–20.0
Effective cleaning distance, L_e (m)	150	200	+33.3

The enhanced performance can be attributed to the optimized design of the cleaning head, which ensures more uniform pressure distribution and greater turbulence near the pipe wall. This improves the detachment of sediments and organic residues, resulting in higher cleaning efficiency (up to 85%). In addition, the modified nozzle geometry allows longer cleaning distances from a single access point (up to 200 m), reducing downtime and operational costs.

Energy analysis indicates that the improved design achieves the same cleaning effectiveness at lower water pressure, leading to a noticeable reduction in energy usage. This directly contributes to the economic and environmental sustainability of the system. The calculated overall efficiency coefficient (K) reached 1.89, confirming that the improved system is approximately 1.9 times more efficient than the conventional model in real field conditions.

CONCLUSION

The conducted experimental studies in the Syrdarya region have demonstrated the technical and economic effectiveness of the improved jet-washing head used for cleaning closed horizontal drainage systems. The results confirmed that the use of the upgraded head significantly enhances the operational performance of drainage-cleaning machines. The machine equipped with the new head achieved a working productivity of 35–40 m/h, with a water consumption rate of 45–50 liters per meter of cleaned pipe, and an effective washing distance of 100–200 meters in one direction.

Compared to conventional drainage-cleaning systems, the improved design allows for an increase in productivity by 15–20%, while reducing water consumption by 20–25% and energy usage by approximately 1.2 times. These improvements not only enhance the efficiency of maintenance operations but also contribute to more rational use of natural resources, particularly water and energy, which is crucial in the arid conditions of Central Asia. Furthermore, the application of the modified washing head extends the service life of underground drainage networks by ensuring better removal of sediment and silt deposits. The obtained results prove that modernization of drainage-cleaning technology can play a vital role in maintaining the reclamation state of irrigated lands and improving their agricultural productivity.

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