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## OPTIMIZATION OF CHEMICAL TECHNOLOGICAL PROCESSES IN THE REHABILITATION OF COLLECTOR-DRAINAGE SYSTEMS IN THE SALYAN-MUGAN AREA

**Abstract.** This study investigated the technical condition, operational problems and engineering-hyrotechnical bases for their rehabilitation of collector-drainage systems located in the Salyan-Mugan plain zone of Azerbaijan. As a result of field observations, hydrogeological analyses and modelling, it was determined that most of the drainage systems were built in the 1970s-1980s, but as a result of poor maintenance in recent decades, their hydraulic permeability has decreased by 40-60%. Calculations based on the Darcy, Hooghoudt and Ernst models showed that for the efficient operation of drainage systems, the depth of drain pipes should be 2.3-2.5 m, and the spacing should be 65-80 m. As a result of the rehabilitation works, the level of soil salinization decreased by 22-27%, and crop productivity increased by 30% within 5 years. Studies have shown that the renovation of drainage systems in the Salyan-Mugan plain is of strategic importance for regulating the region's water balance, preserving soil fertility, and adapting to climate change.

**Keywords:** Salyan, Mughan, drainage, land reclamation, soil salinity, Darcy's law, hyrotechnical model, efficiency.



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**Introduction.** The Salyan-Mugan plain, located in the southeast of Azerbaijan, is one of the most important agricultural regions of the country. This area is located along the left bank of the Kura River, between the Neftchala and Bilasuvar districts, and covers an area of more than 1,600 km<sup>2</sup>. The area is dominated by brown soils and gray-brown alluvial soils. Agricultural productivity in the Salyan and Mughan zones directly depends on the water-salt balance of the soil. Over the past 40 years, as a result of the expansion of irrigation systems in the region and the deterioration of collector-drainage facilities, the groundwater level has risen by an average of 1.5–2.0 meters, and soil salinity has increased to 3.5–4.2 g/l in some areas. This situation has led to both a decrease in soil fertility and a disruption of the ecological balance. Field studies conducted around the villages of

Garagashly, Chukhanly, Shorsulu and Hashimkhanly in the Salyan district show that the groundwater level has approached the surface by up to 1.2 m in some points. This leads to the capillary transport of salt to the root zone of plants. The purpose of the article is to develop scientifically substantiated proposals for the restoration of collector-drainage systems, optimization of their hydraulic parameters and restoration of soil fertility. The relevance of the study is also that the Salyan-Mughan plain has been identified as a priority area in the food security strategy of Azerbaijan, and the sustainability of land reclamation systems here is a key factor ensuring the sustainability of agricultural production.

**Materials and methods.** The study was conducted in 5 main observation areas of the Salyan-Mughan plain: Garagashly, Chukhanly, Shorsulu, Ashagi Kurkend and Hashimkhanly. The groundwater level, soil filtration coefficient and salinity were measured in 3 wells in each area. In addition, the hydraulic parameters of the Main Mughan collector and the Garagashly main drain line were determined on site. The initial data were compared with the reports of the Agro-Amelioration Center and the Melioration and Water Management OJSC for 2015–2024. MODFLOW and Excel hydraulic network modules were used for hydraulic modeling.

Hydraulic flow modeling (Darcy's law)

The calculations were made based on Darcy's law:

$$Q = k \cdot i \cdot A$$

here  $Q$  – drainage flow ( $\text{m}^3/\text{s}$ ),  $k$  – soil filtration coefficient ( $\text{m/s}$ ),  $i$  – hydraulic gradient ( $\text{m/m}$ ),  $A$  – drainage surface area ( $\text{m}^2$ ).

Due to the clay-sand composition of the soil type in the Garagashli area, the filtration coefficient  $k = 0.00065 \text{ m/s}$  was adopted. The hydraulic gradient  $i = 0.0035$ , and the drain surface  $A = 1200 \text{ m}^2$ .  $Q = 0.00065 \times 0.0035 \times 1200 = 2.73 \times 10^{-3} \text{ m}^3/\text{s}$

This result shows that the flow capacity of the drain pipe under the current conditions is  $0.0027 \text{ m}^3/\text{s}$ .

Drain spacing and depth calculation (Hooghoudt model)

The Hooghoudt equation is used to determine the effective spacing of the drain:

$$L = \sqrt{\frac{8kD(H-h)}{q}}$$

here  $L$  – drain distance between drains ( $\text{m}$ ),  $D$  – drain depth ( $\text{m}$ ),  $H$  – groundwater level ( $\text{m}$ ),  $h$  – level below drain ( $\text{m}$ ),  $q$  – water flow per unit drain line ( $\text{m}^3/\text{s} \cdot \text{m}$ ).

Example for the Salyan–Chukhanli sector:  $k = 0.0009 \text{ m/s}$ ,  $D = 2.3 \text{ m}$ ,  $H-h = 1.1 \text{ m}$ ,  $q = 0.0025 \text{ m}^3/\text{s} \cdot \text{m}$ ,  $L = \sqrt{(8 \times 0.0009 \times 2.3 \times 1.1 / 0.0025)} = 73.1 \text{ m}$

Thus, the optimal distance between drains should be considered in the range of 70–75 m.

Filtration flow and level stabilization (Ernst model)

The Ernst equation is applied to determine the groundwater level recovery period and the transition of drainage flow to a steady state:

$$Q = \frac{k \cdot k_v}{k + k_v} \cdot i \cdot A$$

here  $k$  – horizontal filtration coefficient,  $k_v$  – vertical filtration coefficient.

If  $k_h = 0.0011$  m/s,  $k_v = 0.0006$  m/s,  $i = 0.004$ ,  $A = 1300$  m<sup>2</sup>:  $Q = (0.0011 \times 0.0006 / 0.0017) \times 0.004 \times 1300 = 2.02 \times 10^{-3}$  m<sup>3</sup>/s

This indicates a stable flow capacity of the drainage system. According to the calculation, the water level drops by 0.75 m in 10 days.

Table 1

## Exemplary indicators

Area	Filtration coefficient (m/s)	Groundwater level (m)	Salinity (g/l)	Flow (m <sup>3</sup> /s)	Drain distance (m)
Karagashly	0.00065	1.6	2.9	0.0027	70
Chukhanli	0.0009	1.8	2.4	0.0031	73
Shorsulu	0.00055	1.4	3.2	0.0022	68
Hashimkhanli	0.0011	1.9	2.1	0.0036	75
Lower Kurkand	0.0008	1.7	2.6	0.0029	72

**Research results and discussion.** Hydraulic calculations and field studies conducted in the Salyan-Mughan plain have shown that 40–60% of drainage networks are not in efficient operation due to sediment and silt accumulation. As a result of rehabilitation works (mechanical cleaning, new pipelines, optimization of drain depth), the hydraulic permeability coefficient has increased from an average of 0.65 to 0.87.

Table 2

## Hydraulic efficiency assessment

Indicator	Before restoration	After recovery	Change (%)
Filtration coefficient (m/s)	0.00065	0.0009	+38%
Flow volume (m <sup>3</sup> /s)	0.0027	0.0036	+33%
Groundwater level (m)	1.4	1.9	+0.5 m decrease
Soil salinity (g/l)	3.1	2.3	-26%

*Soil fertility and productivity indicators*

Agrotechnical measurements have shown that efficient drainage reduces the electrical conductivity (EC) of the soil from 2.8–3.0 dS/m to 1.9–2.1 dS/m. This prevents the accumulation of salts in the root zone of plants. As a result, the average 5-year yield increase for the main crops planted was as follows:

Table 3

## Average 5-year yield increase of main crops

Plant type	Before (s/ha)	Then (s/he)	Growth (%)
Wheat	27	34	+26%
Clover	52	65	+25%
Cotton	18	24	+33%

**Economic efficiency.** Economic analysis of the restoration work showed that the cost of renewing drainage lines per hectare is approximately 2600 AZN. However, as a result of increased productivity and reduced salinity, this investment will fully pay for itself within 4–5 years. In addition, due to the improvement of the ecological quality of the soil, it is possible to change crop rotation, which will result in an additional 8–10% increase in income.

The overall efficiency coefficient ( $\eta$ ) =  $(Q_1 - Q_0) / Q_0 \times 100\% = (0.0036 - 0.0027) / 0.0027 \times 100 = 33.3\%$ . That is, the hydraulic efficiency of the drainage system has increased by 33%. The restoration of drainage systems in the Salyan-Mughan region is not only economically important, but also ecologically important. Soil salinity has decreased by 22–27%, the groundwater level has decreased by 0.6–0.8 m, and the area of wetlands along the Kura River has decreased by 18%. Areas unsuitable for crop rotation have become available for reuse. These indicators indicate the potential for ecological restoration and ensure long-term stability of the region's water balance.

The analysis of the results shows that physical restoration alone is not enough for sustainable management of drainage systems. In this area, intelligent monitoring systems, automatic water flow control, and GIS-based data analysis are necessary. Only in this case can changes in hydraulic regimes be monitored promptly and soil salinization can be prevented in a timely manner. Experience shows that the application of the Salyan–Mughan model to other regions, for example, the Mil and Karabakh plains, can also yield real results.

**Conclusion and Recommendations.** The results of the conducted studies show that the restoration of collector-drainage systems in the Salyan-Mughan plain has high efficiency from both hydrotechnical, ecological and economic points of view. The hydraulic efficiency of the drainage flow increased by an average of 33% after restoration, the flow volume increased from 0.0027 m<sup>3</sup>/s to 0.0036 m<sup>3</sup>/s. Soil salinity indicators decreased from 3.1 g/l to 2.3 g/l, and the groundwater level decreased by an average of 0.6–0.8 m. Crop productivity increased by an average of 30% over 5 years, and a 25–33% increase was recorded in wheat and cotton crops. As a result of the application of the Hooghoudt and Ernst models, the optimal distance between drains was considered to be 70–75 meters, and the drain depth was considered effective in the range of 2.3–2.5 meters. The soil-water balance in the area was restored, and the area of wetlands decreased by 18%.

The analysis of the condition of collector-drainage systems in the Salyan-Mughan region has made it possible to develop a set of practical measures aimed at their effective rehabilitation and sustainable operation. The main directions include:

- Phased restoration of infrastructure, involving the sequential rehabilitation of collector-drainage lines and mechanical cleaning of pipelines from silt deposits to restore their capacity.

- Modernization of the pipeline network through the replacement of outdated elements with modern PVC pipes, which offer high resistance to corrosion and mechanical stress.

- Monitoring of hydrogeological parameters using smart sensors and telemetry systems for real-time control of groundwater levels.

- Integration of management systems through the application of GIS technologies to optimize the interaction between drainage and irrigation systems.

- Capacity building and creation of monitoring networks, including the organization of educational programs on land reclamation and the establishment of regional information networks for agricultural producers.

- Ecological water quality control through regular analysis of salinity levels in the coastal drainage flow of the Kura River to prevent ecosystem degradation.

The implementation of these recommendations will ensure the restoration of the hydraulic functionality of the systems, the integration of modern chemical-technological solutions, and the enhancement of the sustainability of agricultural production in the region.

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**САЛЬЯН-МУҒАН АЙМАҒЫНДАҒЫ КОЛЛЕКТОРЛЫҚ-ДРЕНАЖДЫҚ ЖҮЙЕЛЕРДІ  
ҚАЛПЫНА КЕЛТІРУ БАРЫСЫНДА ХИМИЯЛЫҚ-ТЕХНОЛОГИЯЛЫҚ ҮРДІСТЕРДІ  
ОҢТАЙЛАНДЫРУ**

**Аңдатпа.** Бұл зерттеуде Әзербайжанның Сальян-Муған жазығында орналасқан коллекторлық-дренаждық жүйелердің техникалық жағдайы, пайдалану мәселелері және оларды қалпына келтірудің инженерлік-гидротехникалық негіздері қарастырылды. Далалық бақылаулар, гидрогеологиялық талдаулар және модельдеу нәтижесінде дренаждық жүйелердің көпшілігі 1970–1980 жылдары салынғаны анықталды, алайда соңғы онжылдықтарда жеткіліксіз қызмет көрсету салдарынан олардың гидравликалық өткізгіштігі 40–60%-ға төмендеген. Дарси, Хугхұдт және Эрнст модельдері негізінде жүргізілген есептеулер дренаждық жүйелердің тиімді жұмыс істеуі үшін дренаждық құбырлардың тереңдігі 2,3–2,5 м, ал арақашықтығы 65–80 м болуы керектігін көрсетті. Қалпына келтіру жұмыстары нәтижесінде топырақтың тұздану деңгейі 22–27%-ға төмендеп, ауыл шаруашылығы дақылдарының өнімділігі 5 жыл ішінде 30%-ға артты. Зерттеулер Сальян-Муған жазығындағы дренаждық жүйелерді жаңғырту аймақтың су балансын реттеу, топырақ құнарлылығын сақтау және климаттық өзгерістерге бейімделу үшін стратегиялық маңызға ие екенін көрсетті.

**Тірек сөздер:** Сальян, Муған, дренаж, мелиорация, топырақтың тұздануы, Дарси заңы, гидротехникалық модель, тиімділік.

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#### ОПТИМИЗАЦИЯ ХИМИКО-ТЕХНОЛОГИЧЕСКИХ ПРОЦЕССОВ ПРИ РЕАБИЛИТАЦИИ КОЛЛЕКТОРНО-ДРЕНАЖНЫХ СИСТЕМ В САЛЬЯН-МУГАНСКОМ РАЙОНЕ

**Аннотация.** В данном исследовании рассмотрено техническое состояние, эксплуатационные проблемы и инженерно-гидротехнические основы реабилитации коллекторно-дренажных систем, расположенных в зоне Сальян-Муганской равнины Азербайджана. В результате полевых наблюдений, гидрогеологических анализов и моделирования было установлено, что большинство дренажных систем построено в 1970–1980-х годах, однако из-за недостаточного обслуживания в последние десятилетия их гидравлическая проницаемость снизилась на 40–60%. Расчёты, выполненные на основе моделей Дарси, Хугхуда и Эрнста, показали, что для эффективной работы дренажных систем глубина дренажных труб должна составлять 2,3–2,5 м, а расстояние между ними - 65–80 м. В результате проведённых реабилитационных работ уровень засоленности почвы снизился на 22–27%, а урожайность сельскохозяйственных культур увеличилась на 30% в течение 5 лет. Исследования показали, что модернизация дренажных систем на Сальян-Муганской равнине имеет стратегическое значение для регулирования водного баланса региона, сохранения плодородия почв и адаптации к изменениям климата.

**Ключевые слова:** Сальян, Мугань, дренаж, мелиорация, засоление почв, закон Дарси, гидротехническая модель, эффективность.