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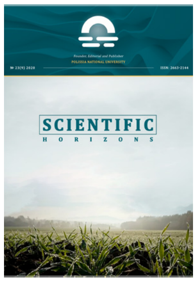

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Optimisation of water use in Kyrgyzstan agriculture: Analysis of modern and traditional irrigation methods to minimise losses and increase efficiency

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Abstract. The study conducted on analysing the characteristics of wastewater composition before and after re-treatment is relevant in the context of environmental protection. The study aims to investigate the characteristics of wastewater before and after re-treatment using a pressure sorption filter. The results of the analysis of quantitative indicators of wastewater revealed that before treatment it was characterised by a wide range of indicators exceeding the normative levels. The greatest

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excess was observed in the content of suspended solids in sample No. 10, where their concentration reached 1,000 mg/l, which exceeded the normative values by 1.43 times. A pressure sorption filter was installed to improve the quality of treatment. The analysis showed that after its implementation, the wastewater indicators improved significantly: the content of suspended solids decreased by 6.67 times, which indicated the effectiveness of this treatment method. After treatment, the content of pollutants decreased to the levels corresponding to the norms. Economic calculation showed low costs for the installation and operation of the pressure sorption filter, which amounted to 22,570 KGS. It should be concluded that in the end, the results showed that the use of a drip irrigation system was cost-effective to implement because the investment amount of 2,765.2 thousand KGS paid off with additional profit in the period of 1.3 years. The results of the study can be used in practice by hydrologists, hydraulic engineers, resource scientists, environmental engineers, ecologists, ecologists-hydrobiologists, specialists in water management and environmental monitoring, as well as decision-makers in the field of ecology and environmental management to develop and implement measures for the implementation of environmental programmes and projects aimed at improving the environmental situation in the region

Keywords: wastewater treatment plant; drip irrigation; sprinkler irrigation; drought; glacier; Lake Issyk-Kul

INTRODUCTION

The research relevance is determined by the shortage of fresh water being the major ecological problem, which leads to the reduction of crop yields and disturbance of ecosystem sustainability. In the study area, there is a problem of insufficient fresh water due to the presence of various anthropogenic and natural factors such as climate change, irrational use of water resources and pollution of water bodies.

G. Issanova *et al.* (2017) revealed that increased mineralisation and predominance of Ca^{2+}, SO_4^{2-}, Na^+ and Mg^{2+} were detected in the river waters of the Issyk-Kul Lake basin. It is necessary to further investigate the ecological consequences of changes in the chemical composition of water for local fauna and flora, as well as for human health, especially considering the alkaline reaction of water and changes in its pH. P. Chevallier *et al.* (2023) found that the climate projection for the period 2020-2060 shows a possible 8.9% decrease in precipitation and, a 0.4°C-1.8°C increase in air temperature. The study can be complemented by the development of recommendations or strategies for climate change adaptation based on the identified trends and modelling results.

R.A. Usubaliev (2022) determined that in the conditions of modern atmospheric warming due to the disintegration of large glaciers into smaller ones, the number of glaciers increased by 46. The study does not sufficiently investigate the modern dynamics and evolution of glaciation processes leading to the reduction of glaciers located in the Ak-Baura and Aravan River basins, as well as their physical changes such as melting, displacement and crevasse formation.

Ch.K. Amanturova (2020) developed economic models to assess the use of water resources of transboundary rivers in Central Asia. The shortcomings of the study include the limited scope of the study, as the study focuses exclusively on water resources in Central Asia, ignoring or omitting other regions, which may make the generalisation of the results incomplete. According to the findings of J.B. Maatkulova and N. Mirbek kyzy (2019), 75% of sewerage engineering structures in Kyrgyzstan for wastewater treatment and disinfection required modernisation or repair works. The gap requiring research was the lack of data on the impact of wastewater pollution on the environment and human health.

M. Mambetaliev (2022) proposed the development of a set of measures for the introduction of modern systems of local treatment facilities for enterprises. The analysis of the issues of ensuring efficient operation and modernisation of local treatment facilities required additional research and development of appropriate strategies for the sustainable development of regional environmental infrastructure. J.P. Chaudhary and P. Jhajharia (2024) while conducting a study on technologies in the field of wastewater treatment concluded that the use of adsorbents based on nanomaterials such as iron, copper and titanium, carbon nanotubes, graphene and polymer-based nanoadsorbents are effective for the wastewater treatment process. The environmental and human health impacts of nanomaterials in the long term have not been sufficiently studied.

The need to improve the wastewater treatment sector is identified. S. Chaouali *et al.* (2024) presented data showing that sludge drying, and biogas production are potentially effective methods to reduce environmental impacts in wastewater treatment. A gap in the presented scientific research is the lack of research to account for potential variables such as climate change and technological innovation. E.D. Ugwuanyi *et al.* (2024) investigated promising technologies in integrating advanced treatment methods such as active sludge systems, membrane technologies and advanced oxidation processes. Additionally, the use of natural wastewater treatment methods such as phytoremediation and aquatic plants including wetlands and greenbelts should be explored.

The study aims to assess the quantitative composition of wastewater before and after a set of measures to remove pollutants contained in domestic and industrial wastewater before its release into water bodies.

MATERIALS AND METHODS

The study employed methods of wastewater analysis, as established by the following regulatory and legal documents: Constitution of the Kyrgyz Republic (2021) (Art. 16), Water Code of the Kyrgyz Republic (2005) (Art. 18), Law of the Kyrgyz Republic No. 53 "On Environmental Protection" (1999). The study applied the spectrophotometric method to determine the chemical oxygen demand (COD). Nephelometric method of analysis to measure the intensity of light flux scattered by solid particles suspended in solution (usually at an angle of 90°). The gravimetric method with residue calcination to measure sulphur dioxide (SO_4^{-2}).

The research was conducted in 2023 in the wastewater management laboratory of Cholpon-Ata city of Issyk-Kul region, in the limited liability company of the agro-industrial complex "El-Dan-Atalyk" of Issyk-Ata district, as well as in the agronomic enterprise "Green Valley" in Issyk-Ata district of Chui region. Figure 1 shows the treatment facilities of the "Vodokanal" enterprise in Cholpon-Ata city.

***Figure 1**. Wastewater treatment facilities of the "Vodokanal" enterprise in Cholpon-Ata city*
***Source:** P. Chevallier et al. (2023)*

The wastewater was treated only mechanically, without biological treatment. This is determined by the fact that at the treatment plant aerotanks, sand traps, and chlorinator room were in non-operational condition, and the building of the compressor unit was in an emergency condition. The area of the pressure filter was calculated according to the formula:

$$F = \frac{Q_{days}}{Tv_{e.f.} - 3{,}6n(w_1 t_1 + w_2 t_2 + w_3 t_3) - nt_4 v_{e.f.}}, \quad (1)$$

where Q_{days} – filter capacity in m^3/day, T – daily operating time, assume 24 hours; $v_{e.f.}$ – design filtering speed; 1.1 m/h, n – number of filter washes per day; $w_1 \rightleftarrows \rightleftarrows t_1$ – intensity in l/sec·m^3 (assume 2 l/sec·m^3) and the duration in hours of initial loosening of the load; 0.017 hours, $w_2 t_2$ – water supply intensity in l/sec·m^2 (3 l/sec·m^3, so-called coal charge) and duration in hours of water-air washing 0.083 h; $w_3 t_3$ – intensity in l/sec·m^2 (2 l/sec·m^3) and washing time in hours, 0.034 hours; t_4 – filter downtime due to washing in hours, 0.33 hours.

For a given useful capacity of a plant with pressure filters Q_{days} = 18.75 m^3/days. The number of pressure filters with the area of one filter 0.4 m^2, should be (2):

$$N = F/f = 1.78/0.4 = 4. \quad (2)$$

Equipment and instruments were used to detect the contaminant content of the samples:

- for measuring acidity (pH) Philips-pw 9421 (Netherlands);
- to measure biological oxygen consumption (BOC) – test unit laboratory oxygen meter Anion 4140 (China);
- to measure chemical oxygen demand (COD) – test unit analyser CD200 (USA);
- to measure suspended solids (SS) test – using BD Phoenix Spec Nephelometer microbiological nephelometer system (USA) depending on the sample permeability;
- for measuring sulphate (SO_4^{-2}) SO_4^{-2} testing unit (USA);
- for phosphate determination and tin chloride estimation (PO_4^{-2}) PYE UHICAM spectrometer Sp 8-100 UV/VIS (Great Britain);
- for measuring nitrite concentrations and estimating content using indole (C_8H_7N) molarity of 0.05 and hydrochloride molarity of 5 Rikka test unit NO_2 (Ukraine);
- for measuring nitrate concentration and assessing the reduction of nitrate to nitrite in acidic media, through the interaction of nitrite with indole (C_8H_7N) Rikka test unit NO_3 (Ukraine);
- for chloride determination and evaluation by titration of potassium chromate (as an indicator) with silver nitrate (as titrant) Rikka test unit Cl^{-1} (Ukraine).

RESULTS

The abnormal drought experienced in Kyrgyzstan in 2023, caused by climatic changes (including a 20-year average temperature increase (2002-2023) from 4.8°C to 6°C) and weak glacier melt, was a serious problem with negative impacts on agriculture, water supply and ecosystems (Kyrgyzstan and water scarcity, 2023). Figure 2 shows an example of the degradation of the Petrov Glacier, located in the Ak-Shyirak mountain range, Issyk-Kul region.

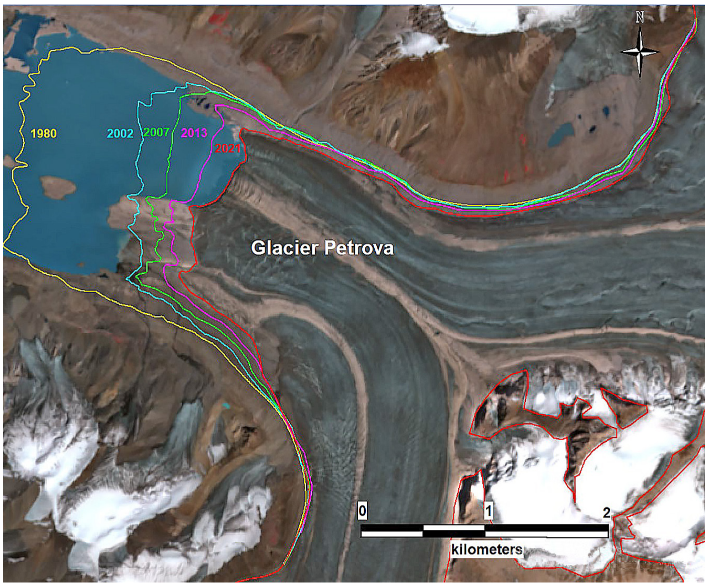

***Figure 2**. Reduction in the Petrov Glacier*
***Source:** More hot days, melting glaciers and droughts: What's driving climate change in Kyrgyzstan (2023)*

The data revealed shows that the area of Petrov Glacier in 1980 was 64 km^2. For 41 years, a gradual reduction of the glacier area was recorded at a rate of 0.084 km^2/year, which resulted in the total area of the glacier being 60.5 km^2 in 2021. The Issyk-Ata district of the Chui region suffered the most from drought and lack of drinking and irrigation water in all regions. In this district, reduction and death of crops, deterioration of soil quality and reduction of freshwater reserves were recorded. The National Statistical Committee of the Kyrgyz Republic (Natsstatcom) reported that in summer 2023, due to drought, the gross yield of wheat decreased by 25.7% (19.1 hwt/ha was harvested) and barley by 29.2% (15.8 hwt/ha was harvested) (National Statistical Committee of the Kyrgyz Republic, 2024a, 2024b).

To combat drought and its consequences, water management measures are important, including organising the efficient use of water resources, introducing irrigation methods, improving the efficiency of agricultural production and rational use of land resources. It is also important to develop infrastructure for water harvesting and storage, as well as to improve warning and response systems for drought emergencies. Following the data presented in Decree of the President of the Kyrgyz Republic No. 23 "On the National Water Strategy of the Kyrgyz Republic until 2040" (2023) Issyk-Kul Lake level decreased by 0.95 m between 2011 and 2021 due to both climatic and anthropogenic factors. In 2023, due to water withdrawal for irrigation, Lake Issyk-Kul was fed only by water from 30 rivers.

There are many advantages of wastewater re-treatment, among them the improvement of the ecological condition of aquatic ecosystems and the reduction of pollutants (Trus *et al.*, 2020). In Kyrgyzstan, this method of wastewater treatment was not widespread. In the Wastewater Management Laboratory of Cholpon-Ata city, Issyk-Kul region, water samples taken from water bodies were analysed. The wastewater considered in this study included domestic, industrial, agricultural and stormwater runoff. As a result of decreasing water resources in the Kyrgyz Republic, a National Water Strategy was developed, which envisaged the future introduction of wastewater recycling and reuse (Decree of the President of the Kyrgyz Republic No. 23, 2023).

The data obtained in the process of characterisation studies corresponding to wastewater before and after re-treatment were reviewed. Table 1 presents the results of pre-treatment wastewater analyses conducted in the environmental laboratory, during which 12 samples were collected from the shallow water of one of the urban beaches of Cholpon-Ata, located between private guesthouses and the pumping station of "Vodokanal", containing pollutants.

***Table 1**. Results of quantitative tests of wastewater received before treatment from 02.02.2023 to 29.07.2023*

No.	Sample date	pH	BOC, mg/l	COD, mg/l	SS, mg/l	SO_4^{-2}, mg/l	PO_4^{-2}, mg/l	NO_2, mg/l	NO_3, mg/l	Cl^{-1}, mg/l
1	02.02.23	6.6	64	89	92	242.4	1.11	0.00	0.00	67
2	18.02.23	6.6	112	142	346	270	0.6	7.20	0.36	57
3	03.03.23	6.6	45	74	41	126.8	1.3	2.32	0.0	74.6
4	16.03.23	6.5	72	126	98	180.3	1.10	0.0	0.0	49.8

Table 1. Continued

No.	Sample date	pH	BOC, mg/l	COD, mg/l	SS, mg/l	SO_4^{-2}, mg/l	PO_4^{-2}, mg/l	NO_2, mg/l	NO_3, mg/l	Cl^{-1}, mg/l
5	16.04.23	6.6	107	162	144	185.4	0.3	2.3	0.3	56
6	24.04.23	6.5	96	122	88	145.8	1.6	9	0.4	42
7	08.05.23	6.3	171	210	248	142	1.7	2.6	0.06	61
8	23.05.23	6.6	171	218	416	234	1.7	5.7	0.3	49.8
9	08.06.23	6.6	112	122	640	288.6	2.4	13.5	0.34	67
10	21.06.23	6.7	72	94	1000	79.5	2.8	0.9	0.011	29.9
11	17.07.23	6.4	146	178	388	201.3	0.11	0.0	0.09	24.10
12	29.07.23	6	76	106	134	176.6	0.10	4.9	0.0	34.9

Source: *compiled by the authors*

Based on the results of the 12 test samples, it is shown that the pH varied from 6 to 6.7, BOC – from 45 to 171 mg/l, COD – from 74 to 218 mg/l, SS – from 41 to 1000 mg/l, SO^{-2} – from 79.5 to 288.6 mg/l, PO^{-2} – from 0.3 to 2.8 mg/l, NO_2 – from 0.0 to 13.5 mg/l, NO_3 – from 0.0 to 0.36 mg/l, Cl^{-1} – from 24.10 to 74.6 mg/l.

According to the requirements of Cholpon-Ata Municipal Enterprise "Vodokanal", the content of suspended solids discharged into the city sewerage system in wastewater should not exceed 700 mg/l. When measuring suspended solids (SS), it was found that the concentration of these pollutants in wastewater at sampling No. 10 was 1000 mg/l and, therefore, exceeded the normative values by 1.43 times. The presence of the exceedance indicates insufficient efficiency of wastewater treatment discharged into Lake Issyk-Kul. To remove suspended solids from wastewater to the requirements of the city Vodokanal, a proposal to improve the treatment facilities of the enterprise "Vodokanal" was developed. The selection of equipment for wastewater treatment from increased content of suspended solids was carried out and a pressure sorption filter was installed.

Selection of the carbon filter was carried out according to the indicator of water quality at the outlet – suspended solids – less than 1 mg/l. Analysis of different types of carbon filters allowed to stop on vertical pressure carbon filter, using absorbent carbon as a loading (internal pore volume 50-110 m^2/g). Using formula (1), the area of the pressure filter was calculated:

$$F = \frac{18.75}{24*1.1\text{-}3.6*1(2*0.017+3*0.083+2*0.034)\text{-}1*0.3*1.1} = 1.78 \text{ m}^2. \quad (3)$$

The results show that the area is equal to 1.78 m^2, which easily allowed to place this filter on the territory of the treatment plant workshop. Table 2 shows the calculation of the cost of installation and operation of the pressure sorption filter.

***Table 2**. Costs for installation of pressure absorption filter*

Costs, KGS/year	
The electricity consumption of the pump is 2,190 kW per year. Cost of 1kW=3.00 KGS. Electricity costs: C_e = 2,190×3.0 = 6.570 KGS/year	65,70 thousand KGS
Current maintenance and repair costs	8,000 thousand KGS
Charges for dumping	2,000 thousands KGS
Amortisation	6,000 thousand KGS
Total	22,570 thousand KGS

Source: *compiled by the authors*

According to the results of the calculation of costs for installation of treatment equipment, it is shown that the amount of spent costs, which amounted to 22,570 thousand KGS, is quite low. Table 3 shows the composition of wastewater after treatment from 02.02.2023 to 29.07.2023.

***Table 3**. Results of quantitative tests of wastewater obtained after its treatment at the pressure sorption filter unit from 02.02.2023 to 29.07.2023*

No.	Sample date	pH	BOC, mg/l	COD, mg/l	SS, mg/l	SO_4^{-2}, mg/l	PO_4^{-2}, mg/l	NO_2, mg/l	NO_3, mg/l	Cl^{-1}, mg/l
1	02.02.23	6.7	29	43	37	175.4	0.2	0.4	26	49
2	18.02.23	6.5	24	51	105	194	0.06	0.47	11.31	58
3	03.03.23	6.8	17	19	29	121.5	0.4	0.2	11.8	49
4	16.03.23	6.8	5	11	33	159	0.4	0.30	0.00	53.5
5	16.04.23	6.7	13	49	39	132.6	0.2	0.3	1.8	48
6	24.04.23	6.7	28	59	47	130	2.5	0.2	3.1	48

Table 3. Continued

No.	**Sample date**	pH	**BOC, mg/l**	**COD, mg/l**	**SS, mg/l**	**SO_4^{-2}, mg/l**	PO_4^{-2}, **mg/l**	**NO_2, mg/l**	**NO_3, mg/l**	Cl^{-1}, **mg/l**
7	08.05.23	6.5	26	107	49	150	0.8	0.34	4.6	53
8	23.05.23	6.6	95	132	47	319	1.2	0.00	3	58.4
9	08.06.23	6.7	26	39	49	248.7	1.8	0.33	11.2	54
10	21.06.23	6.5	40	57	43	138	0.3	0.1	3	48.5
11	17.07.23	6.8	13	51	37	138.8	0.2	1.2	12.4	48.5
12	29.07.23	6.7	15	23	81	153.2	0.2	1.00	19	38.6

Source: *compiled by the authors*

The data shows that after the samples were analysed, the pH values changed from 6.5 to 6.8, BOC – from 5 to 95 mg/l, COD – from 11 to 132 mg/l, SS – from 29 to 105 mg/l, SO_4^{-2} – from 121.5 to 248.7 mg/l, PO_4^{-2} – from 0.06 to 2.5 mg/l, NO_2 – from 0.0 to 1.2 mg/l, NO_3 – from 0.0 to 26 mg/l, Cl^{-1} – from 38.6 to 58.4 mg/l.

A comparison of the obtained results of analyses before treatment and after treatment showed the reduction of quantitative indicators. Thus, the use of a pressure sorption filter unit for the treatment of wastewater containing synthetic surfactants allowed to reduction of the content of suspended solids in treated wastewater – by 6.67 times. Wastewater treatment was a necessary procedure, as the reused water could be used in agriculture for additional irrigation of fields requiring large amounts of water in areas where natural rainfall is insufficient.

Kyrgyzstan was a favourable region for growing maize hybrids of different maturity groups, as the sums of active and effective temperatures provide an opportunity to grow maize with a conditional index of maturity (FAO) up to 500. Annual precipitation during the spring-summer period ranged from 180 mm in the east of Kyrgyzstan to 600 mm in the south-western regions, indicating a lack of moisture for growing crops (Horticultural Crops and Wild Fruit Species in Central Asia, n.d.). In this regard, drip irrigation is appropriate for maize crops in Kyrgyzstan, which allows efficient water consumption and fertigation (irrigation with fertiliser application) during the period necessary for vegetation. This technology is significant as it achieves water savings from 30 to 50% compared to sprinkling irrigation.

Limited Liability Company (LLC) agro-industrial complex "El-Dan-Atalyk" (in Issyk-Ata district) analysed crop breeding and seed production efficiency of using drip irrigation in growing maize hybrids in southern Kyrgyzstan. The study was conducted in the fields of the agronomic enterprise "Green Valley" in the Issyk-Ata district of Chui province. Maize hybrids with FAO 300-400 were grown on this site: KRABAS FAO 300, KERBEROS FAO 310, KAIFUS FAO 330, KVS 6471 FAO 340, KINEMAS FAO 350, KVS 381 FAO 350, CARIFOLS FAO 380. Sowing was carried out on 30.04.2023 using a Kverneland Optima pneumatic precision air seeder with tube confinement (16 mm diameter). The sowing rate of all maize hybrids was 90 thousand/ha, 24 rows of each hybrid were sown.

A starter micro granular fertiliser Agristart – 40 kg/ha and Regent – 4 kg/ha were applied to the crops. The application of post-emergence herbicide MaysTer Power for weed control in maize crops was also provided (the rate was 1.25 l/ha). This field was irrigated with water at a rate of 3800 m³ of water (corresponding to 380 mm of precipitation). During the spring-summer period in the study area, rainfall of 462 mm/ha was recorded. Figure 3 shows the results of the study of the yield of maize hybrids grown on drip irrigation technology.

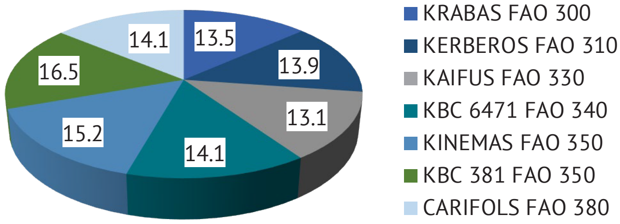

***Figure 3**. The yield of KWS maize hybrids at the application of drip irrigation technology, tonnes/ha*
Source: *compiled by the authors*

In the experimental field, the yield in terms of basic moisture content of 14% varied in the range from 13.1 to 16.5 t/ha. The maximum yield level of 16.5 t/ha was reached by hybrid KVS 381 FAO 350 and KINEMAS FAO 350 – 15.2 t/ha. Figure 4 demonstrates the current harvest moisture levels.

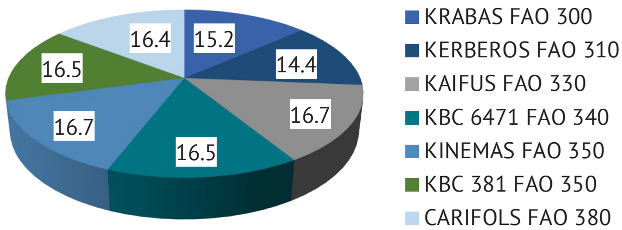

***Figure 3**. Harvest moisture level, %*
Source: *compiled by the authors*

The moisture content at the time of harvest varied between 14.4-16.7%. The lowest harvest moisture content was found in hybrid KERBEROS FAO 310 – 14.4%

and KRABAS FAO 300 – 15.2%. Therefore, it is possible to assert, that when growing properly selected hybrids with increased heat and drought tolerance with FAO 350, it is possible to achieve higher yields at lower harvest moisture. Table 4 demonstrates a comparison of approximate costs and economic indicators of the efficiency of growing maize hybrids on drip and sprinkler irrigation.

***Table 4**. Comparative economic indicators of maize cultivation efficiency on irrigation*

Values	Rain irrigation	Drip irrigation	Deviation	
			+/-	%
Sown area, ha	125	125	-	125
Yield, hwt/ha	125	150	25	125
Gross yield, tonnes	1,025	1275	250	125
Production costs per 1 ha of area, KGS	34,426	3,2524	-1902	94.5
Production costs for growing products, thousand KGS	3,465.1	3,274.9	-190.2	94.5
The sales price of 1 tonne, KGS	7,925	7925	-	100
Revenue from sales, thousand KGS	7,925	9,900	1,975	125
The production cost of 1 hwt, KGS	369.01	284.99	-84	75.6
including irrigation expenses per 1 hwt of production	80.26	50.68	-29.6	46.5
Profit from sales, total, thousand KGS	4,484.9	6,650.1	2,165.2	148.5
including per 1 ha of sowing, thousand KGS	69.6	91.25	21.7	148.5
per 1 hwt, KGS	471	555	84	118.8
Profitability of production, %	154.644	228.86	74.2	-
The volume of investments, thousand KGS	-	2,790.5	-	-
Payback period, years	-	1.3	-	-

***Source:** compiled by the authors*

Maize yield increased by 25 hwt/ha, which made it possible to obtain an additional yield of 250 tonnes. At saving of water and electricity, the level of production costs decreased by 1,902 KGS/ha, or 190.2 thousand KGS (based on the whole area of maize sowing). The cost of 1 hwt of production decreased to 24.4%, and the cost of irrigation itself per 1 hwt decreased by 29.6 KGS, which is 53.5%. The growth of gross production made it possible to get additional revenue from sales in the amount of 1,975 thousand KGS. At the same time, according to calculations, the amount of profit from sales was 6,625.1 thousand KGS, which is 48.5% more than under sprinkling. So, the use of a drip irrigation system was cost-effective to implement: the efficiency level reached the value of 203.8%, which is 74.2% higher than the alternative method, and the investment amount of KGS 2765.2 thousand paid off with additional profit in the period of 1.3 years.

DISCUSSION

Analysing the obtained results of the study, it is possible to conclude that further monitoring of wastewater quality and efficiency of the installed pressure sorption filter should be conducted. The study determined that the Petrov Glacier degradation was caused by a change in the precipitation regime and insufficient precipitation. A similar question was raised by S.A.G. Leroy *et al.* (2021). They obtained results according to which it was found that glaciers of the Tien Shan respond primarily to changes in precipitation rather than temperature. It is difficult to unequivocally agree with this statement, as changes in glaciers in different geographical areas can be caused by a combination of both factors. In some regions, glaciers may respond primarily to changes in precipitation. Increased precipitation can lead to increased snow accumulation on mountaintops, which can favour glacier growth (Skarbøvik *et al.*, 2014). In warmer climates, temperature changes can have a more significant impact on glaciers. Rising temperatures can lead to the melting of ice on mountaintops, leading to a decrease in glacier size (Dzyba & Kyriienko, 2024).

The study that climate change and anthropogenic activity were the reasons for the flow fluctuation of Lake Issyk-Kul. The study of such a problem was carried out by Y. Alifujiang *et al.* (2021). They revealed that climate change was the main cause of runoff fluctuations in the Issyk-Kul Lake basin. The statement of the researchers is valid, as climate change can affect precipitation, snowfall and glacier melt, which directly affects the water level in the lake. However, it is also worth noting other factors such as human activities including the use of water for agriculture and industry. The study determined that climate change can increase or decrease precipitation concentrations in Kyrgyzstan. This was addressed by P. Yang *et al.* (2020). The results of their study indicated a significant increase in interpolated precipitation between 2000 and 2010. This statement is noteworthy, as the results of the reviewed study revealed an insufficient level of precipitation in Kyrgyzstan, which led to a decrease in crop yields.

The study determined that the removal of pollutants from secondary sedimentation tanks of wastewater treatment plants was carried out by mechanical means. A similar scientific study was conducted by A.W. Ahmadi and S. Dursun (2024). Their study determined that the use of cassava in the secondary sedimentation tanks of biological wastewater treatment plants showed complete removal of chemical contaminants. This statement is noteworthy, but it should be noted that to maximise efficiency, a combination of mechanical, biological and chemical wastewater treatment methods should be used to ensure complete removal of contaminants (Bondarev & Gheorghe, 2022). The high efficiency of irrigation methods and their economic benefits were determined. This issue was studied by A. Alamanos and Q. Zeng (2021). Their study investigated the measures of steam use in farming aimed at maintaining agriculture in arid areas. The results obtained from the work carried out do not agree with the findings of the researchers, this study present the results of the efficiency of irrigation methods and evaluate their economic benefits. As such, the efficiency level of drip irrigation reached a value of 203.8%, which is 74.2% higher than that of the rainfed irrigation method.

A similar issue was studied by C. Li *et al.* (2024). They proposed a method based on using a camera system to measure the daily carbon dioxide (CO_2) exchange at different growth stages of maize under drip and flood irrigation methods. According to the results of a study by the researchers found that in the maize ecosystem, drip irrigation showed greater average daily CO_2 uptake by maize plants compared to flood irrigation. This statement can be agreed with, as drip irrigation can indeed increase water use efficiency and improve plant conditions, which in turn can increase photosynthesis and CO_2 uptake (Shevchenko & Nikonchuk, 2022). The study determined that drip irrigation contributed to the increase in crop yields. The study of this issue was carried out by P.H. Rank and B. Vishnu (2019). The study results revealed that the developed sensor-based automated pulse drip irrigation system for irrigating agricultural plants showed high efficiency, as the presented development contributed to maintaining sufficient soil aeration, which helped to improve oxygen penetration into the deep soil layers, stimulating plant root growth and increasing plant productivity. It is worth noting the similarity of this study with that of the researchers as it was confirmed from their findings that drip irrigation helped in improving crop yield.

The results of the calculation show data on the reduction of production cost per 1 hwt of production to 24.4%, as well as information indicating the reduction of maize irrigation costs per 1 hwt by 29.6 KGS (53.5%). A similar issue was studied by M. Şahin (2023). According to the results of his study, it was shown that underground drip irrigation systems were found to be advantageous in terms of saving water, irrigation labour and maintenance. The results obtained in this paper coincide with the findings of the researcher as the efficiency and cost-effectiveness of subsurface drip irrigation was confirmed compared to conventional irrigation methods. To remove suspended solids from wastewater, a solution to install a pressure absorption filter was undertaken. The study of such an issue was carried out by V. Cossich *et al.* (2024). According to the results of their work, a high level of efficiency of drip irrigation system with an emitter tube was revealed, which allows for preventing clogging and increasing the efficiency of water utilisation. The study results of the researchers are noteworthy, as emitters with inbuilt mechanisms to prevent clogging can significantly reduce the likelihood of clogging and maintain a more stable water flow.

Increase of maize yield by 2.5 tonnes/ha when using subsurface drip irrigation has been demonstrated. This was studied by J. Conde *et al.* (2023). During their study, it was revealed that subsurface drip irrigation to a depth of 20 cm had a water productivity of 8.23 kg/m^3, which was the best compared to furrow irrigation and surface drip irrigation and achieved a high olive yield of 9.3 t/ha. This statement should be agreed upon because according to the results of the presented study, subsurface drip irrigation contributed to obtaining an additional yield of 250 tonnes.

The study determined that the application of drip irrigation contributed to increasing crop yields and saving water resources. A.R. Bawa *et al.* (2023). In their scientific paper, they presented a review of the principles of operation of solar photovoltaic pumping systems (SPVPS) used for drip irrigation in agriculture. The similarity of this work with the results of the study of the researchers, according to which it was determined that the use of SPVPS technology reduced greenhouse gas emissions, as well as achieved water savings in agriculture. The study determined that maize yield on the irrigated field plot increased by 25 kg/ha. A. Toffanin *et al.* (2024) studied a similar issue. It is necessary to note the similarity of their work with the results of the presented study, as the results show that soybean yield in the irrigated field increased by 157% in 2022 compared to the non-irrigated control plot. An increase in yield and economic efficiency by using pulse drip irrigation was found. A similar issue was studied by S.M. de Menezes *et al.* (2024). According to the results of their work, the use of pulse drip irrigation provided a reduction in water consumption, increased growth as well as yield of plant stems by 9%. It is possible to note that the conclusions of the experiment of the researchers coincide with the current study regarding the increase in yield and economic efficiency when using drip irrigation for growing maize.

The study demonstrated that economic performance has improved with the use of drip irrigation. This has been studied by U.B. Ntesat *et al.* (2023). Their proposed drip system for intermittent water supply was able to cover an area of 0.000071 m^2 (out of a total area of 0.00119 ha) with spinach crops. From their results, it is shown that the use of a drip system for intermittent water supply helped to increase the off-season production of spinach. Similar results were obtained in this study, showing that improved economic performance resulted in lower production costs and increased financial returns. The study determined that when drip irrigation was applied, maize hybrid KVS 381 FAO 350 and KINEMAS FAO 350 reached a maximum yield of 16.5 tonnes/ha and 15.2 tonnes/ha. A similar issue was studied by A. Tilaye Robi *et al.* (2023). Their study showed that 100% drip irrigation gave the highest yield of 34.31 t/ha compared to 75% and 50%, while the amount of water saved at 75% irrigation was 25% and at 50% reached 50% (comparing drip irrigation with 75% irrigation level, 50% and full 100%). This statement is noteworthy, as the amount of water saved at 75% irrigation can compensate for the yield reduction due to the use of saved water.

The study determined that the lowest level of harvest moisture was found in maize hybrid KERBEROS FAO 310 – 14.4% and KRABAS FAO 300 – 15.2%. A similar issue was studied by Y. Wang *et al.* (2023). According to the results of their study, the duration of crop irrigation exceeding 8 hours was found to exceed the irrigation rate. This statement can be agreed with because under prolonged irrigation the topsoil can dry out, which reduces water absorption and irrigation efficiency (Semenko *et al.*, 2022). The decision was made to use drip irrigation to increase maize yields under conditions when rainfall rates could not always meet the plants' water needs. A similar issue was studied by D.T. Mitku (2022). His study in several regions of Ethiopia confirmed that drip irrigation can be more effective than traditional irrigation methods for vegetable crops when irrigation water is insufficient. The results of the researcher are noteworthy as drip irrigation ensures that water is delivered directly to the plant roots, which minimises water loss through evaporation and runoff. This results in significant water savings compared to irrigation methods such as surface irrigation or spray irrigation.

The superiority of the subsurface method of drip irrigation over surface irrigation has been revealed. F.A.O. Al-Obaidi and S.M.H. Al-Mehmdy (2023) studied this issue. Their study revealed that the subsurface drip irrigation method is significantly more efficient than surface drip irrigation in terms of water consumption. The efficiency of the subsurface drip irrigation method was confirmed by applying the amount of perlite with values of 252.28 kg/m^3 which resulted in a high yield of potatoes. The statement of the researchers that subsurface irrigation can minimise water evaporation and reduce water losses through direct delivery of moisture to plant roots is noteworthy. An increase in profitability of agricultural production was obtained when using a drip irrigation system and it was shown that the investment of 2765.2 thousand KGS was recouped by additional profit in 1.3 years. The study of a similar issue was carried out by I. Cartika *et al.* (2023). Their results revealed that the drip irrigation method can increase yields by 8.39%, reduce costs of chilli pepper production by 13.04% and increase farmers' income by 9.25% compared to manual irrigation. The statement of the researchers is noteworthy as with increased yields and reduced water and fertiliser costs, farmers can indeed achieve increased profits.

CONCLUSIONS

The study analyses included quantitative parameters such as pH, content of organic and inorganic pollutants, and assessment of water quality in terms of its suitability for agricultural reuse. The study provides important conclusions regarding the evaluation of wastewater treatment efficiency of wastewater collected from the beach of Cholpon-Ata before and after the application of the pressure sorption filter.

The results of the analysis revealed that there was a significant reduction in pollutant content after the filter application, indicating the effectiveness of the treatment. Irrigation with water at a rate of 3800 m^3 corresponding to 380 mm of rainfall and with a rainfall of 462 mm/ha resulted in maize yields ranging from 13.1 to 16.5 t/ha. Hybrids with FAO 350, such as KVS 381 and KINEMAS, showed the highest yield levels, reaching up to 16.5 t/ha. At the same time, harvest moisture content ranged from 14.4% to 16.7%, indicating that high yields can be obtained with the right choice of hybrids with increased heat and drought tolerance. According to the results of comparing the efficiency of growing maize hybrids on drip and rainwater irrigation methods, it is shown that when using drip irrigation, the yield increased by 25 hwt/ha, which led to an additional yield of 250 tonnes. The saving of water and electricity reduced production costs by 1902 KGS/ha. The cost of production decreased by 24.4%, and the cost of irrigation of 1 hwt decreased by 29.6 KGS, amounting to 53.5%. An increase in gross production allowed us to get additional revenue from sales – 1975 thousand KGS. Profit from sales increased by 48.5% compared to the method of sprinkling. As a result, drip irrigation turned out to be more profitable: its efficiency reached 203.8%, which exceeded the alternative method by 74.2%. The investment amount was recouped by additional profit in 1.3 years.

In the review of hydrochemical studies of the Issyk-Kul Lake basin, it is necessary to note the extreme insufficiency and limitations of the previous works in this direction. A direction for further research could be the study of the impact of the wastewater treatment process on biodiversity in Issyk-Kul Lake and its vicinity.

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CONFLICT OF INTEREST

None.

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Оптимізація використання води в сільському господарстві Киргизстану: аналіз сучасних і традиційних методів іригації для мінімізації втрат і підвищення ефективності

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Анотація. Дослідження, проведене з аналізу характеристик складу стоків до та після повторного очищення, є актуальним у контексті охорони навколишнього середовища. Мета дослідження – вивчення характеристик стічних вод до та після повторного очищення з використанням напірного сорбційного фільтра. За результатами аналізу кількісних показників стічних вод виявлено, що до очищення вони характеризувалися широким діапазоном показників, що перевищують нормативні рівні. Найбільше перевищення спостерігалося у вмісті завислих твердих речовин у пробі № 10, де їхня концентрація сягала 1,000 мг/л, що перевищувало нормативні значення в 1,43 раза. Для поліпшення якості очищення було встановлено напірний сорбційний фільтр. Проведений аналіз показав, що після його впровадження показники стічних вод істотно покращилися: вміст завислих твердих речовин скоротився в 6,67 разів, що свідчило про ефективність цього методу очищення. Після очищення вміст забруднювачів знизився до рівнів, що відповідають нормативам. Економічний розрахунок показав невисокі витрати на встановлення та експлуатацію напірного сорбційного фільтра, що склали 22,570 сом. Слід зробити висновок, що в підсумку отримано результати, які засвідчили, що використання системи крапельної іригації було рентабельним для впровадження, оскільки сума інвестицій у розмірі 2,765,2 тисяч сом окупилася додатковим прибутком у період 1,3 року. Результати дослідження можуть бути використані на практиці гідрологами, гідротехніками, ресурсознавцями, інженерами-екологами, екологами-гідробіологами, фахівцями з водогосподарювання та екологічного моніторингу, а також керівниками, що ухвалюють рішення у сфері екології та природокористування, з метою розроблення та впровадження заходів із реалізації екологічних програм і проектів, спрямованих на поліпшення екологічної ситуації в регіоні

Ключові слова: очисні споруди; крапельний полив; дощовий спосіб зрошення; посуха; льодовик; озеро Іссик-Куль