# Effectiveness of wastewater use in rice cultivation on basis of water-saving technologies

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**Abstract.** This article covers the results of the scientific research, conducted in the conditions of Khorezm region (Uzbekistan) on cultivation of rice on the basis of seedling as a second crop in the fields after winter wheat. As an introduction of resource conservation technologies in agriculture for cultivation of rice biologically treated water with the help of water hyacinth (*Eichhornia crassipes*) were used in the experiments. Saving irrigation water concerning the purification of waste water from urban public water supply is one of the purposes of the research. According to the research results, while analyzing the physical and chemical content of waste water in the pool with water hyacinth, it was determined that its composition was changed, the water temperature increased from $25^0$C to $29^0$C, the medium changed from acidic to alkaline (6.7-8.2) the color changed from reddish to whitish, the smell disappeared (5.0-0.0), the amount of suspended matters decreased (29.0-0.0 mg/l), the amount of oxygen increased (11.2 mg/l), 5 day biochemical consumption of oxigen ($BCO_5$) decreased (71.4 -10.1 mg/l), the amount of $O_2$ in the oxidation process decreased from 58.2 to 9.2 mg/l and ammonia, nitrites, and nitrates disappeared, besides chlorides decresed up to 40.5-15.3 mg/l, sulfates decreased up to 38.5-12.5 mg/l, phosphates decreased up to 4.2-0.5 mg/l, plant biomass increased from 200 mg/l to 1460 mg/l. At the same time, it was determined that due to the use of wastewater, up to 9250 $m^3$ irrigation water was saved and crop yield was increased to 73 quintals per hectare.
**Keywords.** Water hyacinth (Eichhornia crassipes), wastewater, biological treatment, reproductive phase, vegetative phase, Alanga.

## 1 Introduction

Recent increase of water shortage due to the increase in the population in the world and economic development requires the introduction and implementation of water-conservation

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technologies in the cultivation of all crops, including rice. By reusing of treated wastewater in the introduction of resource conservation technologies in agriculture the amount of irrigation water and use of mineral fertilizers can be decreased, whereas crop productivity can be increased and more expenses can be saved in rice cultivation [1-3].

In rice cultivation in the world 80-90% seedling method is used. Taking into account the soil-climatic conditions and the biological characteristics of the varieties, improving the agrotechnics of cultivation of local and foreign rice varieties and hybrids, increasing their yield capacity, introduction of the world's advanced technologies, and effectively using each hectare of land are the urgent issues of rice cultivating in Uzbekistan [4-6] .

Khorezm region of Uzbekistan has a complex continental climate, with a very high level of water mineralization. This creates difficulties in various branches of agriculture and animal husbandry. The main kinds of agricultural crops is sown by irrigated farming. That is why the annual water consumption of the region is very high [7-10].

Hence it is important to develop the possibilities of wastewater treatment released from various enterprises in the region and reuse in irrigation of agricultural crops with the purpose of decreasing the amount irrigation water. The development and application of special methods of wastewater treatment and disinfection, as well as their use in agriculture, are of great importance [11, 12].

Adebayo et al. [7], Ashiqun Nabi et al. [6] and other scientists in the world carried out researches on the analysis of the composition of wastewater and their biological treatment and achieved important results.

A number of scientific researches also have been carried out on the study of the biological treatment of wastewater from industrial and agricultural enterprises, communal-household, water-waste enterprises and oil processing factories in Uzbekistan with the assistance of water hyacinth and other aquatic plants. And the obtained results were elucidated in the works of several local and national scientists. In the conditions of Khorezm region, scientific research in this field has not been carried out yet.

## 2 Materials and methods

The main idea of the research is to treat wastewater with biological methods and reuse of the treated water for irrigation of agricultural crops. Thus, experiments were conducted on biological treatment of wastewater from communal-household in Urgench city of Khorezm region and using the treated water for rice cultivation.

In the experiment for biological treatment of wastewater water hyacinth (*Eichhornia crassipes*) from the group of higher plants were used, and for growing in the treated wastewater 'Alanga' rice variety was chosen.

Tropical regions of South America is considered as homeland of the genus Eichhornia (*Hyacinth*), and it is a floating plant that grows semi-submerged in water. The stem of Eichhornia plants grows 10-20 centimeters in height, sometimes it can reach 1 meter in favorable conditions [7]. It is a semi-submerged, upright floating perennial aquatic plant. Thick shiny leaves can be 12-15 centimeters wide and 30-50 centimeters long. The length of the roots can be 50 - 60 centimeters and even more [8]. The most common type is thick-stemmed eichhornia (*Eichhornia crassipes Solms*). Our experiments were conducted on this type (Figure 1). This plant is adapted to the conditions of Uzbekistan [3].


**Figure 1.** Aerial photo of the biological ponds of "Khorezm water supply" Ltd.

The rice variety of 'Alanga' was created at the Rice Research Institute of Uzbekistan. It is a hybrid variety by origin. Authors: Pulina P.A., Rikhsieva S. Since 1993, it has been included in the list of Surkhandarya, Syrdarya, Toshket regions. The ear is awned, strongly curved and sparse. The awn is weakly wavy, extending from the bottom to the top. The awned grain makes up 85.0-90.0%, grain semi-round shaped, medium size, clear, white. The weight of 1000 grains is 29.0-30.0 g. The variety is medium-ripening, the vegetation period is 100-118 days. The technological and grain quality of the variety is good: clarity is 71.0-79.0%, rice outcome is 67.0-68.0%, whole rice content is up to 81.0%. Nutrition quality is good. The variety is resistant to lodging and shedding [1].

In order to assess the productivity of plants, recommendations by Katanskaya V.M. were used [4]. Growth, development and biomass of the water hyacinth in wastewater was determined by weighing on scales after every 3, 7, 14, 28, and 30 days. The physical and chemical composition of wastewater, before and after sowing of the plants, were determined according to the general hydrochemical methods by Lure and Strogonov [5, 6]. In determining the discharge of pure and waste water the Cipoletti Weir was used. The weight of the rice grain was determined by weighing on scale.

## 3 Results and discussion

Firstly, in the experiments growth, development and biomass accumulation of water hyacinth and level of wastewater treatment from urban communal-household were observed during 30 days (Table 1).

**Table 1.** Changes in physical and chemical composition of wastewater from communal-household of Urgench city before and after sowing of water hyacinth (*Eichhornia crassipes*) (30 days).

| # | Indicators | Before experiments | After experiments |
|---|---|---|---|
| | | **Wastewater composition** | **Wastewater composition** |
| 1 | Temperature, °C | 25,0 | 29,0 |
| 2 | pH | 6,7 | 8,2 |
| 3 | Smell, points | 5.0 | NA |
| 4 | Color | Reddish | Whitish |
| 5 | Suspended matters, mg/l | 29,0±1,2 | NA |
| 6 | Dissolved oxygen in water, mg/l | NA | 11,2 |
| 7 | $BCO_5$, $mgO_2$/l | 71,4 | 10,1 |
| 8 | oxidation, $mgO_2$/l | 58,2 | 9,2 |
| 9 | ammonia, mg/l | 3,0 | NA |
| 10 | nitrites, mg/l | 0,06 | NA |
| 11 | nitrates, mg/l | 3,0 | NA |
| 12 | chlorides, mg/l | 40,5 | 15,3 |
| 13 | sulfates, mg/l | 38,5 | 12,5 |
| 14 | phosphates, mg/l | 4,2 | 0,5 |
| 15 | plant biomass, g/m$^2$ | 200 | 1460 |

In this case, it was determined that the physico-chemical composition of the wastewater changed, the temperature of the water rose from $25^0$ C to $29^0$ C, the water medium changed from acidic to alkaline (6.7-8.2) the color changed from reddish to whitish, the smell disappeared (5.0-0.0), the amount of suspended matters decreased (29.0-0.0 mg/l), the amount of oxygen increased (0.0-11.2 mg/l), 5 day biochemical consumption of oxigen ($BCO_5$) decreased (71.4-10.1 mg/l), the amount of $O_2$ in the oxidation process decreased from 58.2 to 9.2 mg/l, in addition, ammonia, nitrites, and nitrates disappeared, besides chlorides decresed up to 40.5-15.3 mg/l, sulfates decreased up to 38.5-12.5 mg/l, phosphates decreased up to 4.2-0.5 mg/l, plant biomass increased from 200mg/l to 1460 mg/l.

Scientific research was continued and experiments were carried out on the use of wastewater treated with the assistance of water hyacinth for rice cultivation. Researches were carried out in the biological ponds of the water-waste enterprise belonging to Khorezm water supply Ltd. and in the farm fields located near the enterprise.

Experiments were conducted in 3 variants. In the first variant, water was given based on the development phases of rice under normal conditions. The growth period of rice is divided into 3 phases, 1-vegetative phase, 2-reproductive phase, 3-ripening phase. In turn, each phase consists of 2 periods. The vegetative phase consists of growth and stem elongation, the reproductive phase consists of stem elongation and flowering, and the ripening phase consists of milk development and full ripening. The duration of all 3 phases includes certain days. The growth period is 20 days, the flowering period is 15-20 days, the stem elongation period is 15-20 days, the flowering period is 30 days, the milk development period is 15 days, and the full ripening period is 15 days. The total vegetation of rice requires 115-120 days (in the variety 'Alanga') and the water requirement varies in each phase.

Based on this, in the first variant, i.e. in the control, during the growth period of the vegetation phase 3500 $m^3$, during the tillering period 2500 $m^3$, in total 6000 $m^3$ water per hectare was given. During the stem elongation period of the reproductive phase 4500 $m^3$, during the flowering period 4000 $m^3$, in total 8500 $m^3$ water per hectare was used for irrigation. And during the milk development period of the ripening phase 3000 $m^3$, and during the full ripening period 1000 $m^3$, in total 4000 $m^3$ water per hectare was given. At the end of the experiment, after ripening of rice, the amount of fresh water used in this variant made up 18500 $m^3$ per hectare and the crop yield was 64 t/ha.

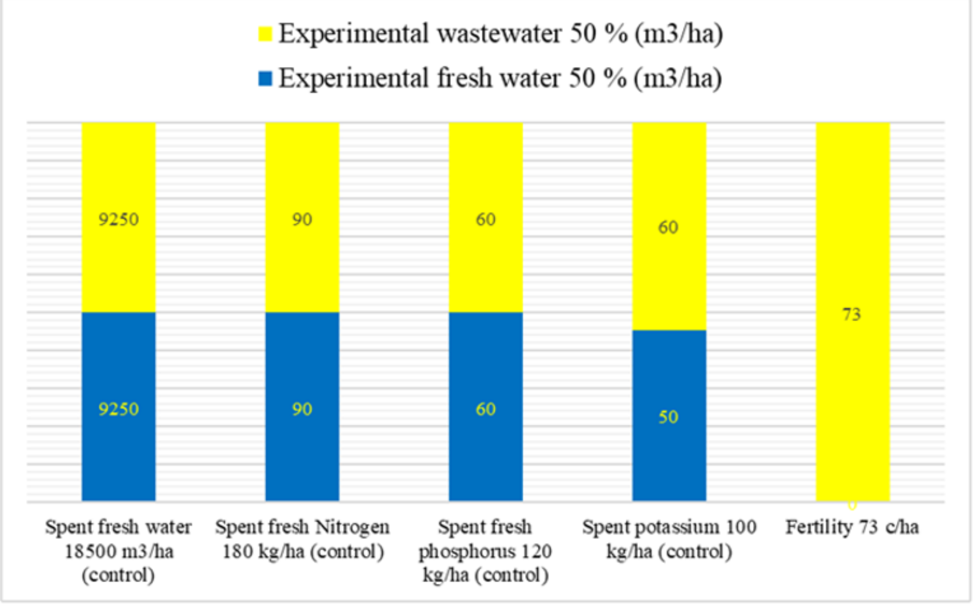


**Figure 2.** Comparative analysis of the amount of fresh water and impurities when rice is grown in clean water (50%) and wastewater (50%).

In the second variant of the experiment, scientific studies were carried out on rice cultivation by adding 25% wastewater to the fresh water. In this case, during the growth period of the vegetation phase 2625 $m^3$ of fresh water and 875 $m^3$ of waste water per hectare was given. During the period of tillering 1875 $m^3$ of fresh water, 625 $m^3$ of wastewater, and in total 4500 $m^3$ of fresh water and 1500 $m^3$ of wastewater per hectare was used in this phase. In the stem elongation period of the reproductive phase 3375 m$^3$ of fresh water, 1125 m$^3$ of wastewater, and in the flowering period 3000 m$^3$ of fresh water, 1000 m$^3$ of wastewater, in total during this period 6375 m$^3$ of fresh water, 2125 m$^3$ wastewater was used per hectare. In the milk development period of ripening phase 2250 m$^3$ of fresh water, 750 m$^3$ of wastewater, and in the full ripening period 750 m$^3$ of fresh water, 250 m$^3$ of wastewater, and total for ripening phase 3000 m$^3$ of fresh water, 1000 m$^3$ of wastewater was used per hectare.

In this variant total amount of used water for the whole vegetation period made up 18500 m$^3$/ha, including 13875 m$^3$/ha fresh water and 4625 m$^3$/ha wastewater. Herein, consumption of clean water was reduced at the expense of wastewater by 4625 m$^3$/ha, and the crop yield was 69 quintals per hectare (Figure 2).

In the 3rd variant of the experiment, scientific research was continued on rice cultivation by adding 50% wastewater to the fresh water. In this case, during the growth period of the vegetation phase 1750 m$^3$ of fresh water, 1750 m$^3$ of wastewater, and during the period of tillering 1250 m$^3$ of fresh water, 1250 m$^3$ of wastewater, in total, 3000 m$^3$ of fresh water and 3000 m$^3$ of wastewater per hectare was used for irrigation. In the stem elongation period of the reproductive phase 2250 m$^3$ of fresh water, 2250 m$^3$ of wastewater, and during the flowering period 2000 m$^3$ of fresh water, 2000 m$^3$ of wastewater, in total, during this period 4250 m$^3$ of fresh water and 4250 m$^3$ wastewater was used per hectare.

In the period of milk development of the ripening phase 1500 m$^3$ of fresh water, 1500 m$^3$ of wastewater, and in the period of full ripening 500 m$^3$ fresh water, 500 m$^3$ wastewater, in total for this phase 2000 m$^3$ fresh water and 2000 m$^3$ of waste water per hectare was used. In this variant also for the entire growing season 18 500 m$^3$ water was used per hectare, including 9250 m$^3$/ha fresh water, and 9 250 m$^3$/ha wastewater. Herein, consumption of fresh water was reduced at the expense of wastewater by 9250 m$^3$/ha, and the crop yield made up 73 quintals per hectare (Tables 2 and 3).

**Table 2.** Annual water consumption of rice.

| **Variants** | **Development phases of rice** (V-vegetative) (Rep-reproductive) (Ripe-ripening) | | **Duration** | **Annual water consumption, m$^3$/ha** | |
|---|---|---|---|---|---|
| | | | | On the development phases | Total |
| 1. Control | V | Growth | 20 | 3500 | 6000 |
| | | Tillering | 15-20 | 2500 | |
| | Rep | Stem elongation | 15-20 | 4500 | 8500 |
| | | Flowering | 30 | 4000 | |
| | Ripe | Milk development | 15 | 3000 | 4000 |
| | | Full ripening | 15 | 1000 | |
| 2. Fresh water + wastewater (25 %) | V | Growth | 20 | 2625+875 | 4500+1500 |
| | | Tillering | 15-20 | 1875+625 | |
| | Rep | Stem elongation | 15-20 | 3375+1125 | 6375+2125 |
| | | Flowering | 30 | 3000+1000 | |
| | Ripe | Milk development | 15 | 2250+750 | 3000+1000 |
| | | Growth | 15 | 750+250 | |
| 3. Fresh water + wastewater (50 %) | V | Tillering | 20 | 1750+1750 | 3000+3000 |
| | | Stem elongation | 15-20 | 1250+1250 | |
| | Rep | Flowering | 15-20 | 2250+2250 | 4250+4250 |
| | | Milk development | 30 | 2000+2000 | |
| | Ripe | Full ripening | 15 | 1500+1500 | 2000+2000 |
| | | Full ripening | 15 | 500+500 | |

**Table 3.** Annual water consumption of rice grown in fresh and wastewater.

| Variants | Total water used, $m^3$/ha | | Total water saved, $m^3$/ha | Productivity, quintals per hectare |
|---|---|---|---|---|
| | Fresh water | Waste water | Fresh water | |
| 1. Control | 18500 | - | - | 64 |
| 2. Fresh water + wastewater (25 %) | 13875 | 4625 | 4625 | 69 |
| 3. Fresh water + wastewater (50 %) | 9250 | 9250 | 9250 | 73 |

## 4 Conclusions

When analyzing the results, in the first variant, the annual water consumption of rice under normal conditions was 18 500 $m^3$/ha, the yield was 64 quintals per hectare; in the second variant, the annual fresh water consumption was 13 875 $m^3$/ha with 4 625 $m^3$/ha of wastewater. In this variant the 4 625 $m^3$/ha of fresh water was saved, and the yield made up 69 quintals per hectare. Annual fresh water used in variant 3 was 9 250 $m^3$/ha and the amount of wastewater was 9 250 $m^3$/ha.

Thus, 9 250 $m^3$/ha of fresh water was saved and the yield made up 73 quintals per ha. It was found that the high yield of rice in the third variant of the experiment was achieved due to the organo-mineral substances in the mixed wastewater in equal amounts to the fresh water, which affected as an additional biofertilizer.

According to the research results, it has been practically proven that biologically treated wastewater can be used for irrigation of agricultural crops. The main point is that at the expense of saved fresh water and fertilizers, the expenses are reduced and net income increases.

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