Engineering biosorptionsal construction for drainage water treatment

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Abstract. Drainage waters pollute water bodies and the environment, however, they can be considered as alternative water resources for agriculture. Now, there is an acute shortage of water resources in the Republic of Kalmykia, and therefore the existing areas are partially used. The solution to the problem may be the technology of reuse of drainage and waste water from the Sarpinskaya watering and irrigation system. For the subsequent use of this water for irrigation, water treatment and purification is required. One of the options for improving the ecological situation is the creation of a biosorption structure (BSS), the principle of which is to mobilize the natural capabilities of self-purification of ecosystems of water bodies, which allows in the future to reuse drainage and waste water for irrigation.

1. Introduction

The hydrogeological regime in the Bolshoi Tsaryn estuary differs from the steppe part of the Sarpinskaya lowland in all respects. The groundwater level in the estuary is more uniform and, on average, groundwater lies 4 meters closer to the surface than in the steppe part. The groundwater in the estuary corresponds to highly saline and even in a number of wells is close to brines (> 50 grams per liter) in terms of salinity in all wells. The salinity of groundwater is almost everywhere below 20 grams per liter in the steppe part. However, in both cases, after rising to a critical level, it is capable of causing intensive secondary salinization of irrigated lands [1-2].

Such probability in the estuary is also due to the presence of a close aquiclude made of Khvalynian clays, over which a highly mineralized overhead water is formed already in the first years of rice cultivation. In addition, if in the steppe part there is a local outflow of groundwater, then in the estuary it is completely absent. Thus, both in the steppe and in the estuary of the Sarpinskaya lowland, especially when using land for agricultural needs, there is a real danger of negative changes in the groundwater regime, deterioration in the quality of irrigated lands and the environmental situation in the zones of the reclamation system [3-5].

The deterioration of the quality of irrigated lands is also promoted by the peculiarities of the structure of the soil cover. Thus, a sharp difference in the water permeability of different soils of the complex leads to the occurrence of seasonal spotty soil salinization, leads to a change in the quality of the crop and a decrease in the effective soil fertility [6].

The solution to this problem can be the development of a technology for the reuse of saline drainage and waste water from the Sarpinskaya irrigation system. For the subsequent use of this water
for irrigation, water treatment and purification is required. The first stage in the development of a technical solution for the treatment and desalination of drainage wastewater was laboratory research to study the absorption of salts by the sorbent and seedlings of wild salt-tolerant plants growing in the Sarpinskaya lowland.

2. Materials and methods

A construction has been developed for carrying out a full-scale experiment. The structure was installed on the territory of the Federal State Unitary Enterprise "Harada, it consists of 10 pressure pipes for water supply with slots, 2 meters long with a diameter of 110 millimeters. On the basis of a field experiment, the use of agroionite as the main sorbent was substantiated; agrotechnical perlite has been chosen as an additional sorbent [7].

![Figure 1. Conducting a full-scale experience with field structures.](image)

During the experiment, it has been found that for further research the most suitable salt-absorbing higher aquatic plants are cattail (Typhalatifolia) and black sedge, or common sedge (Carexnigra).

The next stage in the development of an agroengineering technology for the reuse of drainage and waste water from the Sarpinskaya irrigation system is to draw up a project for a biosorption facility. The structure is designed to supply water with a flow rate of 10 liters per second. The construction has the following sizes: the size of the settling tank (V) L = 6 m, B = 5 m, h = 2.5 m. The size of the filter chamber with sand and diatomite powder NDP-600 (V) L = 0.5m, B = 5m, h1 = 2.5m, h2 = 0.7m .. The size of the complex bioplato (V) L = 51.2m, B = 5m, h = 0.7m. The size of the filter chamber with a mixture of sorbents (V) L = 0.5 m, B = 5 m, h1 = 0.5 m h2 = 0.4 m.

Theoretical and laboratory studies have been carried out to select effective sorbents and substantiate its amount.

Experimentally, the adsorption value has been calculated by the formulas:

\[ \alpha = \left( C_{ish} - C \right) \times \frac{100}{C_{ish}} \]

(1)

Where and are initial and equilibrium concentration of salts in solution:
• Is solution volume;
• Is sorbent weight.

The adsorption value (%) has been calculated depending on the change in salinity (grams per liter).

![Figure 2](image)

Figure 2. Change in the sorption capacity of sorbent mixtures (%) depending on fluctuations in the mineralization index (grams per liter).

The results of calculating the value of sorption have shown that the minimum sorption has been observed when a mixture of vermiculite and perlite has added (from 2.6 to 22.8%). The inefficiency of the selected mixture can be justified by the fact that the mixture has a high density; thereby there is an obstacle to the passage of ions and other soluble substances.

High sorption efficiency was observed in a mixture of agroionite with perlite (86.5-89.1% absorption). This efficiency of the mixture can be explained by different sorption mechanisms [8].

Further, a draft construction of the biosorption facility has been developed. To prevent the destruction of slopes, the BSC has a trapezoidal shape, because, unlike the prototype (Gabion treatment filtering plant), there is no rocky gabion base in the BSS. To reduce the cost of the structure, without prejudice to the sorption properties of the structure, the only way is to arrange the structure at an angle and with trapezoidal slopes. Polymer-bitumen material has been chosen as a waterproofing material, the cost of which is much lower than the cost of gabions. At a right angle of slopes, without the use of concrete, gabions, or other expensive insulating materials, the structure will collapse. The BSS includes four stages of purification, namely: a settling tank, a filter camera with sand and NDP-600 diatomite powder, a complex bioplato, a filter camera with a mixture of sorbents (figure 3).

![Figure 3](image)

Figure 3. Schematic representation of a biosorptional structure.

With the help of a pump, drainage water enters the sump, where suspended solids settle. The settling tank in the BSS also functions as an accumulation tank, providing water intake. In this case, the performance of drainage water treatment is determined by the flow rate of filtration through filter
elements. This flow rate, depending on the size of the structure and, if necessary, can range from 1 to 100 liters per second and more.

From the sump, clarified water is filtered through a chamber filled with sand and diatomaceous earth powder NDP-600, undergoing additional purification from pollutants.

After the filtering chamber, the effluent enters the complex bioplate. The most suitable higher aquatic vegetation growing in the sharply continental climate of the Sarpinskaya lowland in the Republic of Kalmykia, namely cattail (Typhalatifolia) and black sedge, or common sedge (Carex nigra), is planted in the bioplate. Higher aquatic vegetation has been selected in the course of laboratory research to study the salt-absorbing capacity of plants. In order to increase efficiency and optimize work, baffles are located in the bioplateau to regulate the direction of water flow, which is not regulated in other ways.

After the bioplate, the water enters the filter chamber with a mixture of sorbents (agroionite + agrotechnical perlite), where the final post-treatment of the effluent takes place. The indicator of the total mineralization at the outlet, depending on the initial mineralization, which changes during the season no more than 1.3 grams per liter [9-10]. Then, using a drainage pipe, the purified water is returned by gravity to the channel (figure 4).

The calculation of the bioplate parameters for the project has been calculated according to the standard method, but as a result of field and laboratory studies, the dimensions have been adjusted. With the help of partitions in the complex bioplate, it became possible to keep water for the required time in a smaller area of the structure. Due to the zigzag flow of water, the flow rate and cleaning time remain the same in a smaller area of the structure. In addition, the problem of soil leaching required for planting is eliminated.

The developed draft structure allows you to calculate the amount of required materials and their cost.

3. Results
Thus, based on the results of laboratory studies, sorption materials were substantiated that absorb minerals and condition water, and the volumes of sorbent application depending on the volume of water being purified, which will allow during operation to foresee the time for replacing the sorbent. Experience has shown that all sorbents in one or more they absorb salt to a different extent, but the most promising for further research are agroionite, agrotechnical perlite and diatomite.
For the purification of drainage and wastewater, according to research, a biosorptionsal structure was proposed, the elements of which have been studied in natural conditions in Kalmykia for the treatment of drainage and wastewater from the rice irrigation system and on the basis of laboratory studies. A draft design of the said structure for water purification has been developed. The structure is engineered to supply water with a flow rate of 10 liters per second. The structure has the following dimensions (table 1).

| Purification phase                                      | L(m) | B₁(m) | B₂(m) | H₁(m) | H₂(m) | V(m³) |
|--------------------------------------------------------|------|-------|-------|-------|-------|-------|
| Accumulating sump                                       | 6    | 2     | 5     | 2.5   | 2.5   | 50.8  |
| Camera with sand and NDP-600 diatomite powder           | 0.5  | 2     | 5 and 3.3 | 2.5 | 0.7   | 2.61  |
| Complex bioplato                                        | 51.2 | 2     | 3.3   | 0.7   | 0.7   | 94    |
| Camera with a mixture of sorbents (agroionite + agrotechnical perlite) | 0.5  | 2     | 2.8   | 0.5   | 0.4   | 0.63  |
| Summary                                                 | 58.2 | Max=2 | Max=5 | Max=2.5 | Max=2.5 | 206.24 |

4. Discussion
In our constantly changing world, the problem of shortage of fresh water used for irrigation, especially in a sharply continental and continental climate, where there is not enough precipitation and high evaporation, is quite acute. To save fresh water, it is necessary to look for alternative sources of water for irrigation, so as not to deteriorate the condition of irrigated lands and not cause secondary salinization of lands. Simple, environmentally friendly and cheap treatment facilities that do not require expensive maintenance but have the highest possible sorption properties are the most suitable solution. The implementation of this project will allow the use of drainage and wastewater for irrigation and reduce the discharge of low-quality, polluted and saline water. Moreover, economic efficiency can be observed in connection with the introduction of this solution for the use of drainage and wastewater with a smaller intake of fresh water.

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