Design and creation of local mobile plants for stock watering and sheep wool washing units in Kalmykia

A V Arashaev¹, T B Dzhalchinova*, V A Onkaev¹, A N Batrutdinova¹, and A A Mimirishv²

¹Kalmyk State University named after B. B. Gorodovikov, Elista, Russia
²Volgograd State Technical University, Volgograd, Russia

Abstract. The purpose of the study The article deals with the issues of theoretical and experimental study of water purification processes for mobile watering points based on local underground water supply sources and the creation of a mobile installation with a closed cycle of water purification of wool washing, taking into account the regional characteristics of farms of the Republic of Kalmykia. Groundwater abstraction in the area of animal pens is justified; water purification up to the regulatory requirements for watering. The issues of purification production with the use of chocolate clays as a reagent, deposits of which are available in the northern part of Kalmykia, in the Priergeninsky district; determination of the total income from the practice of increasing the efficiency of farming; mobile purification technologies with the reuse of purified water have been developed.

1 Introduction

In arid zones of the Russian Federation, including Kalmykia, sheep breeding is traditionally the basic component of the agricultural economy. The economy of the republic is primarily specialized in pasture sheep breeding.

For the past 6 years there has been a positive development trend in the industry: the number of sheep increased 1.7 times, most of the livestock is concentrated in the farms of rural settlements (46.2%) and in the peasant farms (36.6%). Sheep-breeding and livestock products constitute the basis of employment for the able-bodied population, thereby ensuring the economic security of rural settlements in arid territories.

In practice, all sheep farms represent "autonomous" formations: there are no real organized forms of cooperation between them: the complete absence of industrial slaughterhouses and enterprises for primary processing of meat, no units for primary processing of wool, absence of mineralized water purification for stock watering, no disposal of manure.

As a result, such management method leads to an increased consumption of resources followed by increased production costs and decreased competitiveness of products. One of the ways of resource saving and increasing the production efficiency, hardly regarded in the

* Corresponding author: tdzhalchinova@gmail.com
literature on sheep breeding, is the greening of farms by creating watering sites on the basis of local underground water sources, by creating mobile based closed-loop water cleaning wool washing equipment and by organizing fertilizers for further agricultural usage, pellets and sorbents production from manure.

One mobile unit can serve the cluster of neighboring sheep-breeding farms, servicing the adjacent ones according to the schedule. The quantity and size of mobile water treatment plants for one cluster will depend on the technological parameters of water treatment.

To substantiate these proposals theoretical and experimental studies of water purification processes based on local underground water supply sources are necessary with further design of mobile water purification plant and mobile based closed-loop water cleaning wool washing equipment suitable for usage under regional characteristics of farms in the Republic of Kalmykia.


In general, these works were based on the known techniques common to large livestock complexes. At the same time, this work focuses on the study of increasing the efficiency of sheep farms through the usage of local mobile plants for stock-watering and wool washing.

2 Materials and methods

The technological, operational and economic characteristics made positive evidentiary basis for development of block-modular water treatment plants that municipalities and small businesses use for household, potable, industrial and agricultural purposes [1-3], for cleaning the sewage waters of different categories [4-5].

Groundwater and surface waters in Republic Kalmykia in terms of chemical composition have high salinity, and its usage for watering animals without prior reduction in salt content is prohibited by veterinary standards.

A comparative ecological-economic assessment of water demineralization methods showed that, taking into account local conditions (climatic, geographical, social), the adsorption method using clay minerals has a complex effect. Specifically for the conditions of Kalmykia, it can be chocolate clays (CC), deposits of which are available in some regions of the republic [6].

The main components of these clays are clay minerals and finely dispersed detrital material - pelite (particle size less than 0.01 mm). Clay minerals - the basis of clay rocks - are mainly representatives of layered silicates. They consist of tetrahedral, octahedral and other crystalline networks, alternating in a certain way in each of the minerals. Most of the clay particles are less than 0.004 mm in size. Silty, to a lesser extent, sandy grains are present as impurities in clayed rocks. They are highly dispersed, characterized by a developed surface and are good sorbents (especially for polar substances), as a rule. For clay minerals, as well as for zeolites, along with ion exchange, physical and molecular sorption without breaking the crystal lattice with the release of calcium, magnesium, iron, chlorides, sulfates and residual chlorine ions from water [7] are common.

Experiments targeted for reduction the salinity of groundwater and surface waters were carried out in laboratory conditions using chocolate clays from local deposits: Priergeninsky district of the northern part of Kalmykia (Figure 1) and the neighboring Volgograd region (Eltonskoye deposit).
Fig. 1. Chocolate clay of the Privolzhski region of Kalmykia.

Table 1. Chemical composition of chocolate clay deposits, %.

<table>
<thead>
<tr>
<th>Component name</th>
<th>Eltonskoe 1</th>
<th>Baskunchakskoe 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>SiO₂</td>
<td>63.65</td>
<td>69.4</td>
</tr>
<tr>
<td>CaO</td>
<td>1.97</td>
<td>2.31</td>
</tr>
<tr>
<td>MgO</td>
<td>1.71</td>
<td>2.17</td>
</tr>
<tr>
<td>Fe₂O₃</td>
<td>8.3</td>
<td>12.4</td>
</tr>
<tr>
<td>Al₂O₃</td>
<td>21.43</td>
<td>16.6</td>
</tr>
<tr>
<td>TiO₂</td>
<td>0.71</td>
<td>0.8</td>
</tr>
<tr>
<td>SO₃</td>
<td>&lt;0.1</td>
<td>&lt;0.1</td>
</tr>
<tr>
<td>K₂O</td>
<td>1.97</td>
<td>2.01</td>
</tr>
<tr>
<td>Na₂O</td>
<td>3.27</td>
<td>1.08</td>
</tr>
<tr>
<td>MnO</td>
<td>0.078</td>
<td>0.1</td>
</tr>
<tr>
<td>FeO</td>
<td>&lt;0.3</td>
<td>&lt;0.23</td>
</tr>
<tr>
<td>P₂O₅</td>
<td>0.1</td>
<td>0.1</td>
</tr>
<tr>
<td>Humidity</td>
<td>8.29</td>
<td>9.2</td>
</tr>
</tbody>
</table>

Research methodology: clay samples were milled and dispersed (fractions 0.1 - 1.2 mm, 1.2 - 3.0 mm), fixed weighed portions (1 g of fraction 0.1 - 1.2 mm) were placed in glasses No. 1 - No. 7, where various reagents were added (options 1-7, Table 2). The resulting solutions were mechanically stirred every 5 minutes, control of the salinity was carried out by the electrical conductivity of the liquids (mS) after 30 minutes (Table 2). Initial salinity of water, mg / l: distilled — 5; tap water — 1680; underground water from well — 17800.

Table 2. Indicators of the interaction of waters and acids with chocolate clay.

<table>
<thead>
<tr>
<th>Sample number</th>
<th>Mix composition</th>
<th>Salinity, M, mS</th>
<th>Salinity, M, mg/l</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Distilled water + CC⁺</td>
<td>459</td>
<td>298.4</td>
<td>without activation</td>
</tr>
<tr>
<td>2</td>
<td>Tap water + CC</td>
<td>696</td>
<td>452.4</td>
<td>without activation</td>
</tr>
<tr>
<td>3</td>
<td>Underground water + CC</td>
<td>2712</td>
<td>1762</td>
<td>without activation</td>
</tr>
<tr>
<td>4</td>
<td>H₃PO₄ + distilled water + CC⁺</td>
<td>9021</td>
<td>586</td>
<td>activation</td>
</tr>
<tr>
<td>5</td>
<td>HCl + distilled water + CC⁺</td>
<td>9831</td>
<td>638</td>
<td>activation</td>
</tr>
<tr>
<td>6</td>
<td>H₂SO₄ + distilled water + CC⁺</td>
<td>9851</td>
<td>640</td>
<td>activation</td>
</tr>
<tr>
<td>7</td>
<td>H₃PO₄ + CC⁺ + Underground water</td>
<td>7771</td>
<td>905</td>
<td>activation</td>
</tr>
</tbody>
</table>
The obtained data indicates the possibility of using local chocolate clays (rep. Kalmykia) for treating waters with high salt content in both inpatient treatment plants and in the fields of animals' grazing, which determines the need for research to be done in the dynamic mode.

The second series of studies were carried out in a dynamic pilot-industrial mode on an set of equipment, which included filters with loading (Figure 2): green sand ("GreendSand®") (1), activated carbon (2), reverse osmosis units (3) (4) and membrane filter (5). Additional stage of water treatment from the well was added — a filter with a loading of chocolate clay (fraction 1.2-3.0 mm, loading height — 50 cm (6)), that underwent high-temperature heat treatment (7).

Water for the tests was supplied from a sheep watering hole. The average salt content of water was 2712 mS. The residence time of the water in the installation was 15-20 minutes, the average filtration rate was 1.74 m³/m² h. During the purification process, samples were taken every hour and the salinity of the purified water on each filter was determined by the electrical conductivity (Figure 2). Chemical control was carried out using the average daily sample for pH, alkalinity (A), iron ions (Fe), chlorides (Cl-), hardness (G), nitrites and nitrates (Figure 2).

It can be seen (Figure 2) that the salinity of purified waters from the initial 2712 mS decreased almost to the level of distilled water (350 - 400 mS). It follows from this that, having processed part of the water from the well in the filtration mode on a plant with a sorbent made of chocolate clay, it should be mixed with a certain volume of the original groundwater from the well so that after dilution the mixture would comply with the standards for watering sheep.

The indices of the composition of treated groundwater at the installation (Figure 3) with various filtering baffles are quite close in values and correspond to the standards for watering sheep.

To determine the specific sorption (g of chocolate clay / g of isolated salts), additional series of experiments were carried out on a model solution, that was obtained by dissolving a weighed portion of sodium chloride in a distillate and passing a fixed volume of water through a 120 mm height sorption column filled with clays' sorbent with fractions of 1-5 mm and 5-10 mm. In the process, the volume of filtered water was controlled until a residual salt content reached 0.6 g/l, that corresponds as 6.6 liters for clays with a fraction of 1-5 mm and 3.9 l for 5-10 mm. The sorbent was dried in an oven till constant weight, determining the gained weight as adsorbed salts, after which the specific sorption was calculated: for fraction 1-5 mm — 1.07 g / g, for fraction 5-10 mm — 0.63 g/g.
The obtained values of specific sorption are recommended for use in calculating the need for chocolate clays volumes for watering sheep from surface water bodies and/or groundwater with increased salt content.

With regard to modular installations for washing wool in sheep farms, it were analyzed the features of the composition of industrial wastewater treatment plants and implemented treatment technologies. The analyzed equipment and technologies are multistage and multilayer and are suitable for use in big regions, but for sheep farms they are excessive and cumbersome, which ultimately is economically unacceptable.

Therefore, within the framework of expanding import substitution for sheep-breeding farms, we propose the creation of mobile Primary Wool Treatment (PWT) units based on vehicles equipped with wool washing and wastewater treatment plants. Mobile stations will include a wool washing and drying unit, an equalizer, an electrolyzer, a thin-layer settling tank, a post-treatment and sludge treatment unit [8].

The method of electrocoagulation with soluble iron anodes corresponds to the conditions of mobility with minimal requirements for production areas and volumes for wool washing at sheep-breeding farms so as to standards of wastewater treatment.

In the process of iron anodic oxidation, the formation of a number of hydrated and complex ions is possible: Fe^{2+}, Fe^{3+}, FeOH^+, Fe(OH)_2, FeOH_2^+, Fe(OH)_3, Fe(OH)_2^+, Fe(OH)_4. Ions thermodynamic stability depends on the medium pH, temperature, and redox potential, the values of which are determined experimentally in relation to the composition of industrial wastewater.

3 Results and Discussion

A model waste water was prepared in laboratory conditions, following the Technical conditions for the technology of sheep wool washing: 30 g of short sheep wool, were placed in two containers with a volume of 4 liters of heated tap water at a temperature of 45°C and the wool was washed with stirring for 5 minutes in two versions: using (1) and without using (2) surfactants.

The following results were obtained.

1 - water purification by settling. After wool washing, the water was settled for 30 minutes, after which the water clarity was tested by ring-test, cm and was measured the height of the sediment layer, mm. When standing at the actual temperature of the washing water (40 - 45°C), only precipitating suspended solids were released, and floating (in the form of fats) were not noted. The test was replicated 3 times and the following results were obtained:

- Without surfactants: sediment height 4 mm, transparency 4.5 cm.
- With surfactants: the height of the sediment is 3 mm, the transparency is 0.5 cm, which is explained by the passage of more contaminants into the solution.

After washing with surfactants the wool had visually better quality indicators and could be sent to the consumer. Therefore, in further studies, only wastewater after wool washing with surfactants was used.

2 - the effect of temperature on the release of fats from water. After wool washing the wastewater was chilled in an experimental cryoscopic machine. It was found that when the temperature of the water decreases below 26°C, the fats change from the dissolved state to floating.

3 - the influence of the parameters of the electrocoagulation process on the efficiency of water purification after wool washing was studied on an experimental equipment.

The initial indicators of the model wastewater after wool washing with the use of surfactants: transparency 0.5 cm, temperature 47°C. Steel electrodes, distance between
electrodes 4 mm, DC voltage on the electrodes 15-25 V, current 3A, density 107 A / m², which corresponds to the recommendations of the literature.

Table 3. Parameters of PWT water electrocoagulation purification regime.

<table>
<thead>
<tr>
<th>Electrocoagulation time, min.</th>
<th>Water temperature, °C</th>
<th>Voltage, V</th>
<th>Transparency, cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2</td>
<td>32</td>
<td>15</td>
<td>1.1</td>
</tr>
<tr>
<td>5</td>
<td>34</td>
<td>15</td>
<td>2.3</td>
</tr>
<tr>
<td>7.5</td>
<td>36</td>
<td>20</td>
<td>12.0</td>
</tr>
<tr>
<td>10</td>
<td>38</td>
<td>25</td>
<td>4.5</td>
</tr>
</tbody>
</table>

After electrocoagulation and settling (Table 3), the highest clarity of purified water (12 cm) is achieved after 7.5 minutes of electrical treatment and 15 minutes of settling. Meanwhile, the temperature of the water is suitable for reuse when washing wool.

Therefore it is possible to take cleaning mode operating parameters: an optimal time for electrocoagulation purification is 7.5 minutes at 3A current (current density of 150 A/m²) and 20 V voltage. Purified water settles in a sump for 15 minutes.

4 - post-treatment of waters by sorption. To increase the degree of water purification after electrocoagulation and sedimentation, we studied sorption additional purification of water on a filter with S-VERAD® load, which is one of the cheapest sorbents on the market.

The PWT water purified by electrocoagulation and settling was treated by sorption in a descending mode on a filter with a S-VERAD® load. Filtration rate: 0.0043 l/s* m², temperature 25°C, transparency 21.5 cm.

Waste water purified by electrocoagulation and sorption through the S-VERAD® loading was reused for washing wool: 1/3 volume of wastewater after wool washing was added to the purified liquid, and dirty wool was added at the rate of 50 g per 1 liter of water after shearing sheep. The time of wool washing with stirring was 15-20 minutes.

The quality of the washed wool has not changed. In addition, less hot tap water was required to bring the temperature to 45°C, that required by surfactant wool washing technology.

On the basis of the obtained technological parameters for the purification of wool washing waters, a calculation method, technology and a mobile plant for washing wool of sheep farms have been developed, which was the subject of the invention [8].

Comparison of technical-cost performance of construction and operation of mobile and stationary plants wool washing for sheep farms (1000 sheep) was done. The cost of the stationary structure is 6,665,000 rubles, and the annual operating costs are 1,986,731 rubles per year. The cost of the mobile facility is 2,657,690 rubles, and the annual operating costs are 2,101,188 rubles per year.

It can be seen that under the same initial conditions, construction costs for a stationary plant exceed those for a mobile one by 4,007,310 rubles. Operating costs for a stationary installation are lower by 114,457 rubles (2017 prices).

A mobile unit has an advantage over a stationary one in terms of construction costs (2.5 times cheaper) and slightly worse (5.5%) in terms of operating costs. If we consider that the mobile unit will serve alternately 3-4 farms, its advantage is more than obvious and will determine the key decision to apply it in practice.

Additional annual income of farms from greening technologies will be: 1 — obtaining water from groundwater - 198,300 rubles; 2 — sale of washed wool - 82,150 rubles; 3 — the sale of granular fertilizers from manure - 63,750 rubles.

Total - 344,200 rubles. Thus, the mobile plants for sheep-farms not only reduce the burden on the environment, but seem to be profitable business, which allows them to be recommended for further introduction in sheep-breeding.
4 Conclusion

On the basis of the obtained technological parameters of water purification of wool washing, a calculation method, technology and mobile installation for washing wool of sheep farms were developed, which was the subject of the invention [8]. The comparison of technical and economic indicators of construction and operation of mobile and stationary sheep wool washing plants for farms (1000 sheep) was carried out.

References

2. V. A. Onkaev, M. Yu. Barinov, Principles of construction and organization of a mobile cartridge water supply system for small settlements, Ensuring the protection and restoration of surface water bodies in the Western Caspian Basin District, Sat. stat. Interregional. scientific and technical conf. - Pyatigorsk, 168 -172 (2011)