Theoretical foundations and practical methods of disposal of manure drains of livestock complexes in the Republic of Tatarstan

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Abstract. Irrigation creates a unique way to dispose manure effluents from livestock complexes in specially designated agricultural sewage farms (ASF). Theoretical foundations and practical methods of using manure runoff and selecting crops taking into account their incomplete dehelmintization were developed by the team of authors of this study. It was established that the use of manure effluents after their stepwise preparation ensures the production of 56.9 t/ha of green mass of perennial grass with production profitability from 58 to 86%, 57.0 t/ha of corn and 46.7 t/ha of feed mixtures against 33.8 t/ha on the control version of the experiment. These cultures go through the conservation stage. In this regard, they are environmentally friendly sources of feed in the diets of various groups of animals.

1 Introduction

Modern industrial production of milk and meat provides for the bedding-free livestock keeping, but the use of straw, peat or dry sawdust as a bedding material becomes the basis for an increase in the cost of livestock production [1–3].

On the other hand, the removal of animal excrement by hydraulic washing, the use of water for the care of abdomen, the washing of milk lines, and milking plants, sharply increase the volume of liquid manure, effluents and wastewater, which is 4 times higher than the volume of water of domestic and industrial origin [4–6].

Besides, manure runoff poses a real threat to environmental pollution, spread of infectious diseases of farm animals and humans [7–9].

Therefore, the development of highly efficient methods for the disposal of manure effluents of livestock complexes of the Russian Federation with a content of 2.2 million tons of nitrogen, one million tons of phosphorus and potassium [10] is extremely important from both ecological and practical perspective.

2 Materials and methods

The studies were carried out in 2018-2021 on the fields of Saba LLC Sabinsky and Integrated Agricultural Production Center named after Vakhitov of Kukmorsky municipal districts of the Republic of Tatarstan on typical gray forest soils. The research method corresponded to the method of the All-Russian Williams Fodder Research Institute (2008). Wastewater was used in a ratio of 1:15. The norms and terms of irrigation were determined depending on the biological characteristics of the cultivated crops in the link of the by-farm crop rotation: perennial grass – corn – feed mixtures and the actual moisture content of the soils determined using the Dniester 1 soil moisture meter.

3 Results and discussion

In both farms, the density of livestock per 100 hectares of agricultural land exceeds the national average by 1.5–2.0 times. So, the number of cattle in the Integrated Agricultural Production Center named after Vakhitov is 3,180 heads, including 1,180 dairy cows. In addition to cattle, the farm is engaged in the production of pork – 2,757 heads and horse meat – 37 foals and horses. Large volumes of liquid manure, slurry and wastewater are formed while removing manure with hydraulic washing, washing of milking plants, a milk tank and sanitary care for animals. They are accumulated in huge specially built 3 liquid manure tanks (Figure 1).

The results of the studies showed that the most acceptable way to dispose of this waste is to ensure their stepwise preparation. At the same time, the polydisperse mass of slurry, liquid manure, wastewater enters the slurry collector through concrete pipers and, depending on density, is naturally divided into 3 parts. Particles with a density of more than one settle at the bottom of the slurry collector, a layer of concentrated liquid is formed above them, then part of the organic substance accumulates on its surface with a density less than one (feed remains, etc.).
Fig. 1. Satellite image of the Vakhitov Agricultural Complex with three livestock wastewater receivers.

After that, the liquid layer is pumped out into a special tank for clarification, and the dense precipitate is burned out using loaders and transported for application to a separate section of the agricultural irrigation field.

The analysis of samples of dense manure sediment carried out at the Tatarsky Center of Agrochemical Service showed that the nitrogen content, depending on its origin, ranges from 0.26 (cattle waste) to 0.39% (horse origin). The same pattern is typical for potassium (0.38 and 0.58%, respectively). However, in terms of phosphorus, this ratio changes fundamentally, since in dense horse manure its content is 5 times lower than potassium. In this regard, in our opinion, additional application of phosphorus fertilizers should be considered a mandatory agro-technical technique in agricultural sewage farms.

The final stage of treatment – clarification of wastewater – is carried out in horizontal tanks. After that, 1 m³ of wastewater is diluted with clean water (15 m³) and supplied to the agricultural sewage farms during the irrigation of crops.

Incomplete deworming of other disease-causing pathogens under the influence of solar radiation during the step-by-step treatment of manure effluents was also revealed in the course of study. In this regard, we can say with great confidence that it is necessary to cultivate only those crops in agricultural sewage farms that pass through the conservation stage (silage, haylage making or grass flour production) and through the body of animals. Only in this it is possible to exclude human infections. These are, first of all, maize for silage, perennial grass and feed mixture for silage (Table 1).

<table>
<thead>
<tr>
<th>Crop</th>
<th>Green yield, t/ra t/ha</th>
<th>Increase</th>
<th>Feed unit content</th>
<th>Feed unit gross yield, t/ha</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>t/ha</td>
<td>%</td>
<td></td>
</tr>
<tr>
<td>Introduction of dense effluent of cattle manure, 40 t/ha</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (no fertilizer)</td>
<td>33.8</td>
<td>–</td>
<td>47.3</td>
<td>0.19</td>
</tr>
<tr>
<td>Perennial grass per sowing year</td>
<td>56.9</td>
<td>23.1</td>
<td>73.4</td>
<td>0.20</td>
</tr>
<tr>
<td>Corn</td>
<td>57.6</td>
<td>23.8</td>
<td>68.1</td>
<td>0.18</td>
</tr>
<tr>
<td>Feed mixes</td>
<td>46.7</td>
<td>12.9</td>
<td>49.9</td>
<td>0.20</td>
</tr>
<tr>
<td>HCP_d6</td>
<td>0.32</td>
<td></td>
<td></td>
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<tr>
<td>Effluent application</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (no fertilizer)</td>
<td>32.4</td>
<td>–</td>
<td>–</td>
<td>0.19</td>
</tr>
<tr>
<td>Perennial grass per sowing year</td>
<td>48.5</td>
<td>16.1</td>
<td>49.7</td>
<td>0.20</td>
</tr>
<tr>
<td>Corn</td>
<td>52.0</td>
<td>19.6</td>
<td>60.5</td>
<td>0.18</td>
</tr>
<tr>
<td>Feed mixes</td>
<td>45.1</td>
<td>12.7</td>
<td>39.2</td>
<td>0.20</td>
</tr>
<tr>
<td>HCP_d6</td>
<td>0.29</td>
<td></td>
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</tbody>
</table>
The use of liquid manure and clarified wastewater is a very effective way to increase crop yields. The following patterns were revealed based on the results of yield accounting:

- without the introduction of manure effluents the productivity of irrigated gray-forest soils does not ensure the regulatory indicators – 6.16 and 6.42 t/ha of fodder units against the regulatory indicator of 6.50 t/ha;
- against the background of the use of both wastewater and dense sediment of cattle manure the highest yielding crop was maize for silage with a green mass yield of 52.0 and 57.6 t/ha, and in terms of gross yield of feed units there were no equal to perennial grass – 9.70 and 11.38 t/ha, respectively;
- feed mixtures (peas + oats + sunflower) occupied an intermediate position between control and perennial grass in terms of green mass yield and gross yield of feed units.

![Fig 2. Corn cobs in milky ripeness against the background of the introduction of 40 t/ha of dense sediment of cattle.](image)

![Fig 3. Perennial grass with the introduction of wastewater.](image)

Consequently, corn and perennial grassin agricultural sewage farms differ in the rate of biomass accumulation, which are profitable to cultivate from an economic point of view.

The cost of gross production (CGP) was determined by the formula:

\[ \text{CGP} = Y \cdot \text{Feed unit} \cdot 8 \text{ thousand rubles, where} \]

- \( Y \) – green mass yield;
- Feed units – content of feed units in green mass;
- 8 thousand rubles – sale price of 1 ton of oat grain in 2019 (1 ton of feed units nutritionally equal to 1 ton of oat grain – the world standard).

Calculations show a close correlation between the cost of gross production and the gross yield of feed units: the higher the first indicator, the larger the second value. Thus, perennial grass with the introduction of 40 t/ha of dense sediment of cattle manure runoff ensured the yield of 11.38 t/ha of feed units in the amount of 91.4 thousand rubles, which is 78 % higher than the control (Table 2).

<table>
<thead>
<tr>
<th>Crop</th>
<th>CGP, RUB, in thousands/ha</th>
<th>TC, RUB, in thousands/ha</th>
<th>CNI, RUB, in thousands/ha</th>
<th>Profitability, %</th>
<th>Feed unit cost, RUB, in thousands/t</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Introduction of dense effluent of cattle manure, 40 t/ha</strong></td>
<td></td>
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</tr>
<tr>
<td>Control (no fertilizer)</td>
<td>51.4</td>
<td>43.8</td>
<td>7.6</td>
<td>17</td>
<td>6.8</td>
</tr>
<tr>
<td>Perennial grass per sowing year</td>
<td>91.4</td>
<td>58.1</td>
<td>33.3</td>
<td>57</td>
<td>5.1</td>
</tr>
<tr>
<td>Maize for silage</td>
<td>83.1</td>
<td>60.4</td>
<td>22.7</td>
<td>38</td>
<td>5.8</td>
</tr>
<tr>
<td>Feed mixes for haylage</td>
<td>74.7</td>
<td>56.3</td>
<td>18.4</td>
<td>33</td>
<td>6.0</td>
</tr>
<tr>
<td><strong>Effluent application</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control (no fertilizer)</td>
<td>49.3</td>
<td>38.4</td>
<td>10.9</td>
<td>28</td>
<td>6.2</td>
</tr>
<tr>
<td>Perennial grass per sowing year</td>
<td>77.6</td>
<td>41.8</td>
<td>35.8</td>
<td>86</td>
<td>4.3</td>
</tr>
<tr>
<td>Maize for silage</td>
<td>74.9</td>
<td>45.6</td>
<td>29.3</td>
<td>64</td>
<td>4.8</td>
</tr>
<tr>
<td>Feed mixes for haylage</td>
<td>72.2</td>
<td>50.9</td>
<td>21.3</td>
<td>42</td>
<td>5.6</td>
</tr>
</tbody>
</table>

The same pattern was characteristic in the block of studies using clarified wastewater: 77.6 and 57%, respectively.
The total costs (TC) are calculated according to the process chart. For the cultivation of perennial grass they turned out to be much less compared to corn and feed mixtures: in the first block of experiment the analyzed value was 58.1 thousand rubles/ha against 60.4 thousand rubles/ha when cultivating corn. This is due to the fact that perennial grass is sown once, but used 3-4 years. The cost of perennial grass tending is also less, since unlike corn, it does not require inter-row cultivation. Most importantly, the nodule bacteria of perennial grass with alfalfa content additionally absorb air nitrogen and provide the largest gross yield of feed units.

The reduction in the total cost of cultivating all studied crops using clarified wastewater should also be emphasized, since in this process there are no additional costs for their use: wastewater is delivered together with irrigation water. As a result, conditionally net income (CNI) determined by the formula $CNI = CGP - TC$ on crops of perennial grass is 35.8 thousand rubles/ha, corn – 29.3 and feed mixtures – 21.3 thousand rubles/ha against 33.3; 22.7; 18.4 thousand rubles/ha on options with the introduction of dense sediment of manure runoff of livestock complexes using special spreaders terra variant 585.

In economic calculations, the most important indicator is the profitability (P) of production of a particular product. It is determined by the formula:

$$P = \frac{CNI}{TC} \times 100\%.$$  

According to this indicator, our studies distinguish 2 crops: perennial grass – 57 and 86 % depending on the methods of using cattle manure and maize silage with cobs in milk ripening – 38 and 64 %. For comparison it should be noted that in rich feed production of the Republic of Tatarstan the profitability of these crops does not exceed 25-30%, which is a significant proof of the high economic efficiency of irrigation of feed crops with the introduction of manure effluents from livestock complexes.

The calculations of the economic efficiency require the cost of production using the following formula:

$$C = \frac{TC}{Feedunitgrossyield},$$

since it shows how much money is spent from the production of 1 ton of feed units. Depending on the culture and methods of manure disposal, the cost of feed production from perennial grass ranged from 4.3 to 5.1 thousand rub/t, corn – from 4.8 to 5.8 and feed mixtures – from 5.6 to 6.0 thousand rub/t. With a conditional sale price of 1 ton of feed units of perennial grass of 8 thousand rubles, the farm would receive from 2.9 to 3.8 thousand rubles of cash from perennial grass (8-4.3 and 8-5.1), corn – from 2.2 to 3.2 and feed mixtures – from 2.0 to 2.4 thousand rubles.

In addition to compliance with the recommended technology for the use of manure and the choice of crops in obtaining high economic returns, the territories of agricultural sewage farms are particularly important, provided they comply with the following ules developed by us:

- the length of the field must correspond to the length of the acquired sprinkler;
- the field configuration for front wide-grip sprinklers should be rectangular with a length-to-width ratio of 3:1 or 2:1;
- it is desirable to place the long side of the field across the north-west winds;
- it is strictly forbidden to place the ASF above the main and distribution pipelines;
- pipelines shall be located along the boundaries of fields. The number of pipelines shall be minimum, economically reasonable;
- sprinkler machines shall operate sequentially from one culture to another according to the rational process system;
- circular sprinkler machines shall provide no more than two crops with irrigation water, the transition to another irrigation area is carried out mechanically;
- the edges of irrigated area are sown with other mesophytic or xerophytic cultures to form rectangular fields for circular sprinkler machines.

Most importantly, special attention should be paid to the forestry arrangement of the ASF territory. The forest strip created along the perimeter of the ASF should help reduce wind strength, increase relative air humidity, reduce moisture evaporation and spread ammonia odor and act as a biological drainage to prevent waterlogging of irrigated lands. In order to solve the latter problem, it is necessary to plant moisture-loving tree species (poplar, birch, aspen, and tall shrubs (willow, alder, willow) with a planting scheme of 3x1 m (3m distance between rows and 1m in rows), with a total width of 9–12 m and an openwork structure.

### 4 Conclusion

The disposal of manure effluents of livestock complexes in agricultural sewage farms and the forestry development of the ASF territory are a promising direction of increasing the volume of feed production with low cost and high profitability (up to 86%). On the other hand, it is of great environmental importance, especially for the Republic of Tatarstan with a cattle density of more than 1 million heads.

### References

