Investigation of the method of dehydration of organomineral fertilizer based on liquid waste of pig farms

D I Monastyrskiy, G N Zemhenko and M A Kulikova

Federal State Budget Educational Institution of Higher Education "Platov South-Russian State Polytechnic University (NPI)"; Novocherkassk, Russia

E-mail: danya.monastyrskij.95@mail.ru

Abstract. The article deals with the research of possible methods of dehydration of organomineral fertilizers based on liquid waste of pig farms. Technologies and various methods of sludge dewatering after reagent treatment of liquid waste from pig farms and related processes are analyzed. Based on the results of the analysis, a comprehensive scheme is proposed that can meet the needs of processing waste from large pig farms and provide farmers with a sufficient amount of available fertilizers. The dependences of the dynamics of moisture removal and dewatering on the devices used are obtained. It is established that the productivity of aggregate operations for the removal of excess liquid at the first stage and dehydration of organomineral fertilizers can be expressed in qualitative indicators — different structure of the final product-organomineral fertilizer in the form of powder, granules or plastic mass. The interaction between individual operations in the technological chain is considered, the technical indicators of various scenarios of dehydration of organomineral fertilizers are analyzed.

1. Introduction

The dewatering process is widely used as a method of removing moisture using various equipment and installations. Materials containing excess moisture are subjected to dehydration.

Liquid removal is, on the one hand, a diffusion process, on the other — a thermal process. This is a complex technological process, as a result of which the properties of the material change.

Overall costs can be reduced by a high level of automation, despite the higher associated investment costs. An analysis of existing studies shows that a single-step dehumidification operation may be sufficient. Two-stage operations, consisting of the removal of the liquid fraction by the cheapest possible method, are attractive from an economic point of view. The process of dewatering using a system of several stages, allows you to efficiently use the capabilities of the equipment used.

The growing demand for food, energy, and materials has increased the role of recycled waste products in the biology-based economy. However, the industrial production of waste products is still in a developing state [1-12].

In [1-5], the technologies and mechanisms of various methods of effective sludge dewatering are considered.
Scientists [6-8] comprehensively study the technology of improved sludge dewatering and related processes [9-12].

2. Results and discussion

This paper is devoted to the technical analysis of various large-scale dewatering systems for organomineral fertilizers with an emphasis on the effective use of equipment capabilities. The primary removal of the liquid fraction and dewatering are considered as a single operation.

There is no ready-made solution for drying organomineral fertilizers obtained during complex waste processing. In the complex processing of pig waste, organomineral fertilizers are obtained, which are then applied to the soil. But these fertilizers cannot be fully called a marketable product because at the first stage, fertilizers are obtained in liquid form. Obtaining organic fertilizers in the form of powders and granules with a low moisture content will reduce transportation costs, increase storage life, automate the process of applying fertilizers to the soil, and make them more attractive to farmers [13-15].

To commercialize organic fertilizers as a commodity, the cost of producing products from liquid organic waste must be reduced. The production of organic fertilizers consists of three main stages: 1) production by complex waste processing, 2) dewatering, 3) granulation. The efficiency of a sequential combination of operations depends on the individual performance of each block. The choice of the operation of the unit for the first stage of obtaining organomineral fertilizer also affects the performance of the following units at the dewatering stage.

Obtaining organomineral fertilizers can be carried out in two strategies: 1) obtaining fertilizers in liquid form and their subsequent introduction into the soil; 2) obtaining fertilizers with their subsequent dehydration and introduction into the soil in the form of pellets. In the case of the second strategy, obtaining fertilizers involves drying, which allows you to accumulate fertilizers during the off-season and make the product available for transportation, the most convenient and effective application to the soil. The choice of strategy is also determined by the limitations of the operation, such as the maximum possible concentration, the viscosity of the concentrate, etc. d.

![Figure 1](image-url). Dependence of the irrigation area on the amount of fertilizers applied (Hectare).
The use of granular fertilizers allows you to process large areas while using smaller amounts of fertilizers. During dehydration and subsequent granulation, the concentration of fertilizers in relation to the volume increases significantly. Also, the process of applying granular fertilizers can be automated, which reduces the time and material costs for their use.

We conducted research on available technologies for obtaining and dehydrating organic fertilizers. The results are shown in figures 2 and 3.

Figure 2. Scheme of fertilizer dewatering using a hydrocyclone and a vacuum blade dryer (a); dynamics of fertilizer dewatering (b).

Figure 2 (a) shows a diagram showing the process of removing moisture using a hydrocyclone and a vacuum paddle dryer. Figure 2 (b) shows the process of dewatering the fertilizer using a hydrocyclone and a vacuum paddle dryer. This method can be used for drying small volumes of liquid fertilizer in the absence of a continuous process. Despite the fact that the hydrocyclone allows you to remove up to 60% of the liquid, the output is a fertilizer with a moisture content of 98%. Reducing the humidity to 10-20% with a vacuum paddle dryer requires a lot of time and energy, and the volume of the dryer is not used efficiently enough.

Figure 3. Scheme of fertilizer dewatering using a decanter and a belt dryer (a); dynamics of fertilizer dewatering (b).

Figure 3 (a) shows a diagram showing the process of removing moisture using a decanter and a belt dryer. Figure 3 (b) shows the process of dewatering the fertilizer using a decanter and a belt dryer. The decanter allows you to remove up to 80% of the liquid, while forming a fertilizer with a moisture content of 80-85%. The belt dryer is able to lower the humidity to 5-3%. This scheme can be used if there is no need for granulating fertilizer, since for drying with subsequent granulation, the use of a belt dryer is considered impractical, since its capabilities will not be used to the full.
Based on the proposed options, an optimal model for drying organic fertilizers is compiled, shown in figure 4.

![Diagram of fertilizer dewatering](image)

**Figure 4.** Scheme of fertilizer dewatering using a hydrocyclone, decanter, vacuum blade dryer and granulator (a); dynamics of fertilizer dewatering (b).

Figure 4 (a) shows a diagram showing the process of removing moisture using a hydrocyclone, decanter, vacuum blade dryer and granulator. Figure 4 (b) shows the dynamics of fertilizer dehydration. This method is optimal for establishing a continuous process, dewatering large volumes of fertilizers and preparing fertilizers for storage, transportation and application in the form of pellets. Each unit is operated in an optimal mode, using the possibilities of waste recycling with the lowest possible specific energy consumption.

The main purpose of this study was the quantitative analysis of combinations of dehydrating complexes. It is based on a technical and economic assessment of production and dewatering systems operating on an industrial scale. The considered criteria are increasing the shelf life, reducing the volume of application, increasing the efficiency of transportation, and the possibility of automating production.

The results of the analysis provide an idea of the effectiveness of dewatering process chains in terms of resource conservation.

The approach and methods shown in figure 4 illustrate the steps and operations that are used for dehydration. Available technologies for dewatering organic fertilizers include a sump, a hydrocyclone, a decanter, a vacuum paddle dryer, and a granulator. For the dewatering stage, other options can be used, depending on the requirements for seasonality, the volume of fertilizers obtained.

The technologies described in figure 4 have the potential to achieve a high humidity reduction, and do not require an additional dewatering stage.

To assess the effectiveness of the technology under consideration, a model approach is used. The models concern the I / O mass balances for each block operation. The function of obtaining and dewatering is to separate the fertilizer flows into a concentrated product flow and a concomitant liquid flow. Efficiency is achieved by using the maximum working volume of the devices. This is possible thanks to several stages of dewatering, each unit removes the maximum possible amount of moisture for it. Thanks to this, the fertilizer, which is maximally dehydrated by the previous aggregates, enters the individual aggregates. For example, the preliminary removal of moisture by a hydrocyclone (60%) and a decanter (20%) can increase the productivity of a vacuum blade dryer by introducing fertilizer with a moisture content of 80%, which gives a much larger volume of dry product at the output.

For each operation, the maximum size of the equipment is applied. If the required capacity exceeds the maximum capacity of the equipment, additional units are installed. For example, if the power of three blocks is lower than the required one, then the fourth block is installed. It is assumed that all installed units have
the same power. During the fertilization season, it is not necessary to dehydrate the entire volume of fertilizers produced, some of them can be applied in liquid form. At the same time, in some periods of time, the ability to process concentrate can reach the maximum permissible values, for example, when eliminating lagoons that accumulate waste for a long time, or increasing the volume of waste in the case of increasing the productivity of a pig farm.

The costs of sludge dewatering consist of:

- Expenses for the purchase of land, buildings, and equipment for production needs.
- Annual expenses calculated as depreciation write-off of the cost of fixed capital—the product of investment costs by the return coefficient.
- Expenses related to current production needs—materials, personnel, resources, etc.

Two-stage operations, such as dewatering with a decanter and dewatering with a belt dryer, or dewatering with a hydrocyclone and dewatering with a vacuum paddle dryer, are attractive in terms of equipment costs. But at the same time, energy costs increase. Thus, the energy costs of using these systems are comparable to the capital investment costs of using a hydrocyclone, decanter, vacuum blade dryer, and granulator. As a result of using this system, the equipment works more efficiently at each stage. The additional investment in a higher degree of automation can be offset by the lower labor costs and energy consumed by the equipment to achieve a similar end result. Although there is no doubt that qualitative data analysis plays an important role in the preliminary analysis of existing potential dewatering technologies. A quantitative model-based approach can provide a deeper economic understanding.

3. Conclusions

The analysis of this study revealed the strengths of the technologies used. It should be noted that the costs of obtaining and dewatering organic fertilizers arise from the use of capital expensive single operations. However, the results of this study showed that in energy-efficient technologies with low capital costs, there are additional costs due to the high humidity of the fertilizer.

The productivity of aggregate operations for the removal of excess liquid at the first stage and the dehydration of organomineral fertilizers can be expressed in qualitative indicators - the different structure of the final product-organomineral fertilizer in the form of powder, granules or plastic mass. The interaction between individual operations in the technological chain is considered, the technical indicators of various scenarios of dehydration of organomineral fertilizers are analyzed. It is established that the most effective use of a complex of two stages, including several devices, selected for the required parameters of production and application of fertilizers.

The maximum capacity of fertilizer dewatering methods is limited and requires a large number of aggregates when working with large pig farms. However, there is a variation in their use depending on the seasonality and dynamics of liquid waste generation.

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