Effectiveness of the adsorption properties of clay in relation to the disposal of organic waste from poultry farms

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Abstract. This article discusses an important problem related to the disposal of organic waste from poultry farms. Bird droppings are one of the main sources of environmental pollution and consume significant resources for disposal. The search for effective and environmentally safe methods of disposal of such waste is very relevant. The article focuses on the study of the adsorption properties of a clay accumulation site. Due to the insufficient knowledge of this technology of manure burial, full-scale modeling was performed to determine the effectiveness of protecting the components of the ecological and geological environment. It is shown that under conditions of complete water saturation, the liquid fraction from the organic waste layer will easily seep through the voids and cracks of the clay layer and poison the underlying soils and groundwater. It is concluded that a clay special site alone does not provide guaranteed environmental safety of the environment. Engineering and environmental recommendations are given on the mandatory combination of this method of burial of litter with a litter made of a layer of sealed film coating.

1 Introduction

Poultry farming is the leader among all sub-sectors of animal husbandry in Russia: the share of poultry in total meat production is 43.5% (for 2023). The Ministry of Agriculture of Russia expects that in 2024 the volume of production of eggs and poultry meat in the country will grow, and the profitability of the industry already allows investing in new projects. At the same time, if, for example, 15-18 kg of egg mass is obtained from one laying hen in one year, then during the same period the chicken secretes 55-73 kg of litter. When growing broilers, 3 kg of manure is additionally obtained for each kilogram of meat obtained [1]. The amount of litter produced per year reaches tens and even hundreds of thousands of tons.

Fresh chicken manure, according to Rosprirodnadzor Order No. 242 dated 22.05.2017 "On Approval of the Federal Waste Classification Catalog", belongs to hazard class III – moderately hazardous waste that violates the environmental situation with subsequent restoration of environmental components for about 10 years.

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It is well known that it is impossible to use bird excrement in its pure form as fertilizer. Fresh chicken manure is not used directly for fertilization (it, among other things, dramatically increases the nitrate content in agricultural products), so in the past it was mainly used to prepare compost with peat or straw. Dry manure is a loose organic fertilizer containing 4-6 percent nitrogen, 2-3 percent phosphorus and 2-2.5 percent potassium. It is transportable and can be stored for a long time. The most dangerous thing is that untreated thermally chicken manure is an excellent breeding ground for pathogens of acute intestinal infections that can live and multiply in manure piles for years.

Wastewater from poultry farms contains various nitrogen compounds – ammonium nitrogen, nitrogen of organic substances, oxidized forms of nitrogen (nitrites and nitrates) [2].

At the end of 2022, the sectoral program "The use of secondary resources and secondary raw materials from waste in agriculture for 2022-2030" was approved as part of the implementation of Law No. 248-FZ of July 14, 2022. "On by-products of animal husbandry..." and the Federal project "Closed-loop Economy". The program provides for the mandatory processing of organic waste from agricultural production, including chicken manure, for their disinfection in accordance with sanitary and epidemiological requirements and further use as organic fertilizers to ensure the reproduction of fertility of agricultural lands. According to the decree of the Government of the Russian Federation dated October 31, 2022 No. 1940 "On approval of requirements for the circulation of animal by-products", specialized sites must have monolithic concrete or hermetically welded film coatings, or have a clay cushion with a thickness of at least 20 centimeters at the base.

Consequently, poultry farms have a huge amount of toxic organic waste, which must not be disposed of, but processed profitably. One of the main reasons for the occurrence of environmental hazards from the accumulation of manure is the poor quality of technological operations of improper storage and transportation. At the moment, there are many technologies for the burial, composting and processing of chicken manure, but most importantly, there are no economically and environmentally acceptable ones at the same time. Examples are stories when manure is delivered to agricultural fields, accumulation sites are sealed with a scraper and manure piles are formed. All actions are performed without environmental protection. To meet environmental requirements, larger agricultural holdings fill concrete platforms with special slotted floors, install fans and an awning, and purchase agitating machines. Accordingly, under such favorable conditions, the composting cycle is reduced to 14 days, but these are isolated and expensive cases.

In this regard, the purpose of this work was to develop recommendations on the method of engineering and environmental protection of soils and groundwater underlying the storage of chicken manure.

To achieve this goal, the following tasks were solved:

1. Implementation of the process of burial of chicken manure on the example of full-scale modeling;
2. Conducting systematic monitoring and reporting during the experiment;
3. Summarizing the results, taking into account the chemical analysis of the content of individual components in solutions obtained experimentally, followed by engineering and environmental recommendations.

2 Materials and methods

To test the resistance of the clay layer to infiltration of the liquid fraction from chicken manure, the experiment was carried out under conditions of constant water saturation.

Clay has a number of unique qualities that are very important for ensuring environmental safety:

- the ability to swell and soak;
- powerful sorption properties;
- water-resistant qualities.

In this regard, protective clay screens are used in the construction of landfills, as well as vertical protective walls for the localization of dangerous objects.

Clays differ in their physico-chemical type. Montmorillonite clays (which are the basis for bentonite clays) have a high prospect of being used to create engineering barriers due to their microstructure. Gaps between the structural elements of the ribbon chain contribute to the deposition of water, organic compounds, and heavy metals in them, as a result of which clay can swell with an increase in volume by 10 times and have better sorption. Kaolinite (white) clay, on the contrary, is characterized by low swelling, is prone to compaction, which is convenient for its use as protective shields. This type of clay was used during full-scale modeling (Fig. 1.).

A PET container with a volume of 5 liters was used, so the process will be more visual due to the transparency of the walls.

Filling of the selected container is carried out in a ratio of 1:2, where 1 part of unprocessed fresh chicken manure with a moisture content of 60-70% is 10 centimeters thick, and 2 parts of a layer of kaolinite clay 20 centimeters thick, having previously brought 1.5 kg of dry matter to a viscoplastic state. All available space was densely filled to obtain reliable results.

Fig. 1. Kaolinite clay, used in the experience.

3 Results and discussion

The beginning of the experience is 22.02.2024. It took 1 liter of water to saturate the layer of chicken manure. During the week, the water level was kept at a height of 2 centimeters above the first layer. At a temperature of 22 degrees, the clay layer dried out, began to condense and separate from the walls of the container. As a result, the solution according to the principle of least resistance began to spill freely outside the container (Fig. 2). To continue the experiment, it was necessary to reduce the diameter of the container, create an obstacle for the free passage of water along the walls of the bottle. A 1 liter plastic bucket with a pre-cut bottom was suitable in size (Fig. 4). After that, from 4.03.2024 to 14.03.2024, the water was very slowly used to feed and swell the contents of the container, but the clay effectively

adsorbed the upper liquid layer with a total mass of 2 liters. From 16.03.2024, a liquid solution of manure found a crack in the clay layer, formed due to a seasonal increase in air temperatures complete with home heating, which again proves the instability of this system (Fig. 5).

From 19.03.2024 to the present, the experiment has been continued in several stages after careful preliminary compaction of the clay layer. The conditions of full moisture saturation remain, but the drying processes have a tendency, which violates the tightness of the screen (Fig.3). The color of colloidal solutions is dark brown with a greenish tint due to eutrophication processes.

Clay is a rather difficult material to use, statically unstable even under ideal conditions. When environmental conditions change to critical (high humidity, frost, drought) it cracks, settles and clumps. Also, mechanical damage and deformations will contribute to the fact that the usefulness of a clay screen at the sites of laying bird droppings as a means of protecting environmental components is questionable and minimal. Liquid fractions with abnormal amounts of pathogenic and disease-inducing microorganisms, toxic elements seep into the soil and aquifers through the cracks formed. The full-scale modeling demonstrated the low quality of the use of the litter burial technology indicated in the regulatory documents. A negative factor is also the constant cutting of a certain part of the screen during the process of stirring and removing the finished part of the litter.

Fig. 2. The process of deformation of the clay screen as a result of drying.

Fig. 3. A system of voids and cracks formed in a compacted clay layer.

4 Conclusions

Full-scale modeling of the possibility of using a clay screen as an insulating element in places where chicken manure is stored has demonstrated its low efficiency. This is due, on the one hand, to a violation of the continuity of the screen during high and low temperatures. The emerging crack system represents the migration routes of contaminated solutions from the waste accumulation body to the underlying soils of the aeration zone and groundwater.

A mandatory element of activity within the sites of accumulation of waste from poultry farms is the work of scrapers for stirring and moving litter. This process additionally disrupts the continuity of the clay screen, both in terms of its power and in terms of porosity and fracturing of the clay material.

It is necessary to adjust the Decree of the Government of the Russian Federation dated October 31, 2022 No. 1940 "On approval of requirements for the circulation of animal by-products" regarding the use of clay screens with a capacity of 20 centimeters at the base of chicken manure storage sites. The possibility of using film coatings at the base of a clay screen is also problematic, since the movement of equipment on the surface of the storage area can cause deformations and tears of the film coating. Due to the high level of waste toxicity and the specifics of the technology of handling chicken droppings, we consider it advisable to use concrete foundations for their accumulation and storage sites.

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