Problems of Waste Management at Poultry Plants and Ways to Address Them

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Abstract. The paper analyzes scientific literature on manure recycling and systems of waste management at two poultry plants that use different technologies of poultry housing and manure disposal and calculates the volumes of waste generation for two plants. The authors suggest an economically and ecologically efficient manure utilization technology, consider the feasibility of replacing traditional fuel with the one produced by manure recycling and calculate expected profits and the payback time of equipment.

1. Introduction
In many regions of Russia, poultry plants steadily increase production of eggs and poultry meat. However, except their main product, poultry housing and operation zones simultaneously produce proportional amounts of wastes – poultry manure, sewage water, nonfood products of killing rooms, fallen poultry, hair, and feathers, manure being produced in most considerable quantities [1]. Poultry plants allocate vast territories for storing manure that produces unpleasant odors. Precipitation makes microorganisms, nitrogen and phosphates from manure flow into water bodies. Russia lacks practical application of manure recycling technologies, and storage volumes of manure are growing, especially in autumn and winter.

The aim and purpose of the paper is to assess the scale of the problems related to generation and accumulation of huge amounts of poultry manure and to suggest ways to address them depending on the technology of poultry housing.

The tasks are as follows:
1. To assess environmental effect of poultry manure and poultry plants in general.
2. To study technologies available for manure recycling.
3. To analyze waste management systems at two plants that use different poultry housing technologies.
4. To determine the scale of the problem by analyzing calculations of waste generation volumes at the plants under investigation.
5. To assess the feasibility of waste recycling technologies according to a set of criteria and to suggest a most optimal technology of manure recycling for the plants under investigation.
6. To assess economic and ecological efficiency of the suggested manure recycling technologies.
7. To calculate the payback period of the suggested technologies.
2. Methods
To solve the problems related to accumulation and permanent storage of manure it is necessary to use the most efficient technologies for its recycling. The most significant factor of choosing the technology of manure recycling is manure moisture that depends on poultry’s ration, housing technology (floor, litter, or cage housing) and the way of manure disposal (scraping, ribbon conveyor, flushing) [2].

To assess the scale of the problem we analyzed operations, waste management systems, and calculated waste generation volumes at two poultry plants with different poultry housing and manure disposal technologies (Table 1). The first poultry plant (Primorsky Region, Russia) practices floor and litter housing and uses dry process of manure disposal, and therefore the manure contains low level of moisture. The second poultry plant (Kamchatka Region, Russia) houses the poultry in cages, and uses flushing process of manure disposal, which results in the manure containing high moisture levels.

| Indicator                        | Poultry Plant One (Primorsky Region) | Poultry Plant Two (Kamchatka Region) |
|----------------------------------|--------------------------------------|--------------------------------------|
| Poultry house capacity           | 361 000                              | 235 000                              |
| Housing                          | floor/litter                         | cage                                 |
| Way of manure disposal           | scraping and transportation to the manure storage area | flushing to the manure pits, pumping out and transportation to the manure storage area |
| Place of manure storage          | manure storage area                  | manure storage area                  |
| Manure recycling / sales         | occasional sales to individuals and businesses | supply under government contracts and occasional sales to individuals |
| Manure generation volume, tons per year | 14 450                               | 7 190                                |

We calculated standard generation volumes for all types of wastes by using approved methodologies and recommendations [3-5] and by applying different methodologies to different types of wastes.

Annual manure generation volume was calculated by (1), (2) and (3):

\[ W = T \times C \times W_d \] (1)

where \( W \) – annual amount of waste (tons per year); \( T \) – poultry operation time in one cycle; \( C \) – annual number of cycles; \( W_d \) – daily amount of waste (tons per day).

\[ C = \frac{D_y}{D_c} \] (2)

where \( D_y \) – number of workdays in a year; \( D_c \) – duration of one cycle.

\[ W_d = N_p \times m \times S \times 0.001 \] (3)

where \( N_p \) – number of poultry; \( m \) – average weight of a single poultry bird of standard age (kg); \( S \) – specific manure generation factor; 0.001 – conversion factor of manure weight to tons. \( S = 5\% \) of the weight of a single poultry bird per day.

According to the calculation of waste generation volumes, 99% of the total amount of waste on the both poultry plants is poultry manure (Figure 1). The analysis of the waste management systems
showed that the both plants accumulate the manure on their territories. It was also calculated that at the first plant the annual generation volume of low-moisture manure is 14 450 tons, while the second plant generates 7 190 tons of manure. The problem of manure utilization is urgent for the both poultry plants.

Figure 1. Waste generation volumes at the poultry plants under investigation, tons per year.

Depending on manure moisture, various recycling technologies may be applied. We suggest the following criteria for choosing the most appropriate technology:

- waste-free or low-waste technology of recycling,
- no long and labor-consuming stage of waste preconditioning,
- no necessity for large waste recycling areas,
- short recycling terms and no necessity for accumulating large amounts of waste, and
- ecological and economic efficiency.

The criteria above and the analysis of scientific literature on manure recycling [6-9], made it possible to single out the most effective recycling technologies. The most economically and ecologically effective technologies for recycling low-moisture manure are incineration of preliminarily dried manure in dust furnaces and obtaining biogas by anaerobic methane fermentation. The most effective technology to utilize high-moisture manure is obtaining biogas, as it does not require manure preconditioning and separation into solid and liquid fractions.

Figure 2 shows a technology for obtaining heat by incinerating manure in a dust furnace after preliminary drying in a Biomass Processing System (BPS) that is applicable for recycling low-moisture manure. Both low-moisture and high-moisture manure can be effectively recycled by obtaining biogas, a technology based on anaerobic methane fermentation [10] (Figure 3).

Figure 2. A technology for drying and incinerating manure.
Figure 3. A technology for obtaining biogas.

To assess the efficiency of the technologies we considered ecological and economic benefits of their implementation (Table 2). Currently, poultry plants have expenses related to heating, hot water supply, and environmental payments.

Table 2. Economic and ecological benefits of manure recycling technologies.

| ECONOMIC BENEFITS                      | BEFORE implementation | AFTER implementation |
|---------------------------------------|------------------------|----------------------|
| 1. Heating and hot water supply.      |                        | 1. Cost saving due to fuel replacement. |
| 2. Environmental payments.            |                        | 2. Cost saving due to reduction in environmental payments. |
| 3. Pollution charges.                 |                        | 3. Sale of fertilizers. |
|                                       |                        | 4. Avoidance of pollution charges. |

| ECOLOGICAL BENEFITS                   |                        |                        |
|---------------------------------------|------------------------|------------------------|
| 1. No necessity for manure storage areas. |                        |                        |
| 2. Minimal atmospheric pollution.      |                        |                        |
| 3. No soil pollution.                  |                        |                        |
| 4. No pollution of water bodies.       |                        |                        |

The calculation of pollution charges showed that the most significant expenditures are connected with environmental payments for manure disposal. Such payments are calculated by (4).

\[
P = W \times P_d \times F \times F_{st} \times F_2 \times F_i
\]  

(4)

where \( P \) – payment for waste disposal (rubles per year); \( W \) – annual amount of waste (tons per year); \( P_d \) – standard payment for disposal of waste belonging to a certain hazard class (rubles per ton); \( F \) – extra factor (F=5 or F=0.3); \( F_{st} \) – ecological significance factor of a business location area; \( F_2 \) – (F2=2) extra factor for Russia’s Far North and other equivalent territories (applied to Kamchatka Region); \( F_i \) – inflation factor in the year of calculation.

The implementation of manure recycling technologies will give the poultry plants incomes from economizing on environmental payments, as well as from fuel replacement.

To assess the profitability of replacing traditional fuel with alternative one we calculated the fuel replacement rate based on

1) quantity of the fuel used,
2) expected output of biogas,
3) calculated production of dry manure,
4) heating value of calculated volume of raw waste.
Depending on the amount of manure, equipment capacity and current heating expenses the estimated savings will constitute from 70 to 100 per cent.

3. Results and Discussion
The analysis of the waste management systems at the two poultry plants that use different housing technologies made it possible to prove the magnitude of the problems related to manure accumulation and urgency of manure recycling technologies.

By implementing manure recycling technologies, the poultry plants will reduce negative environmental effects and expenses for heating and hot water supply, avoid significant payments and gain profit from selling by-products. The calculated savings and incomes of the two plants made it possible to estimate profits from implementing manure recycling technologies. According to formula (5), the profit of the two poultry plants will constitute 100 million rubles.

\[ P_r = S_{ep} + S_r + I_{bf} \]  

where \( P_r \) – profit gained by implementing the technology, rubles; \( S_{ep} \) – savings from reducing environmental payments for waste disposal, rubles; \( S_r \) – savings from fuel replacement, rubles; \( I_{bf} \) – income from selling bio fertilizers, rubles.

Unlike in case of manure drying and incinerating, biogas technology also produces bio fertilizers that serve as a source of considerable income. Therefore, for poultry plants with low-moisture manure it is more profitable to apply biogas technology.

Considering the economic aspects of manure recycling and equipment costs, we calculated that the average payback time of biogas installations with a cogeneration unit is one year (taking into account only the cost of essential equipment).

The calculations show that alternative fuel (chicken manure) is fully competitive with conventional energy sources. It is proved that the heat from incinerating manure and biogas is economically effective to use for production purposes, as well as for heating and hot water supply.

4. Conclusion
In the present paper, we analyzed scientific literature on manure recycling and we also analyzed operations and waste management systems at the two poultry plants using different housing and manure disposal technologies and calculated waste generation volumes at the two plants.

We suggested a most economically and ecologically effective manure recycling technology, assessed the possibility of replacing conventional fuel with that produced from recycled manure, calculated the estimated profit and payback time of the equipment.

The work presented in the paper leads us to arrive at the following conclusions.
1. The major ecological problem at poultry plants is connected with generation and accumulation of significant amounts of manure and with the lack of new technologies for its recycling.
2. Accumulation and storage of manure leads to pollution of all the components of the environment.
3. Regardless of moisture level in chicken manure, the most economically and ecologically effective recycling technology is obtaining biogas by anaerobic methane fermentation.
4. The implementation of the new technology will make it possible to not only minimize negative effect on the environment components but also reduce expenses for heating and hot water supply, avoid significant ecological payments and gain considerable profit from selling by-products.
5. The average payback time of biogas installations with a cogeneration unit is one year, apart from savings on ecological payments and excluding operating expenditures and infrastructure costs.
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