Choosing the benchmark technology for cleaning poultry house emissions from malodorous substances

A V Nazarova, O I Sergienko, N R Molodkina and V Ye Efremova
ITMO University, ul. Lomonosova, 9, St. Petersburg, Russian Federation

E-mail: naz.nastasya@gmail.com

Abstract. The article considers the problem of unpleasant odor from poultry factories. It is proposed to use a system for standardizing the permissible impact of malodorous substances on the environment based on the best available technologies. The article assesses technologies in regards to their possible use at poultry houses. The appropriateness of using the selected benchmark technology to reduce the smell of poultry houses is confirmed; the environmental and economic effectiveness of such technology is taken into account.

1. Introduction
Poultry farms are a significant source of environmental pollution. The problem of emissions of polluting odorous substances into the atmospheric air and the pungent odor generated during the disposal of waste from poultry farms is significant for residents of nearby buildings. [1] Poultry facilities and litter storages are the main sources of unpleasant odors spreading over long distances.

The unpleasant odor of the exhaust gases is most often caused by the simultaneous impact of many substances on the human organs of smell at once, these substances are often difficult to identify; thereby, it complicates the task of monitoring, rationing and deodorization. The multicomponent nature is especially characteristic of malodorous gas emissions of biological origin, the sources and emissions of which are enterprises for processing products and animal waste, municipal waste and water treatment, as well as microbiological industrial processes, etc.

The variety of sources releasing malodorous substances into the atmosphere, differences in local conditions require an individual approach when choosing a method of cleaning and deodorization. The main direction in solving the problem of reducing and eliminating atmospheric pollution by malodorous substances is to improve production processes and equipment based on the best available technologies.

Of great importance is the problem of developing systems for monitoring and regulation of malodorous substances in the exhaust gases and atmosphere.

2. Objects and methods of research
The object of study is a poultry farm in the Leningrad region. The poultry house contains 80,000 heads, the average live weight of a chicken is 1.45 kg; the working time of the house is 5840 hours per year.

The research methods are a logical decision-making approach on the best available technology, a method for assessing quantitative analysis and information processing.

3. Results and discussion
Table 1 shows the concentration of pollutants. Ammonia, mercaptans, hydrogen sulfide, amines and increased microbial contamination are found in the poultry farm. [1-3] The concentration of malodorous...
substances does not exceed the maximum permissible values, but the concentration of such substances exceeds the perception threshold, which is a quantitative indicator reflecting the problem of odors. The situation is aggravated by a high concentration of dust, which adsorbs pollutants on its surface and is an additional source of odorant distribution [4]. Treatment plants are not available at the poultry farm.

There are many technologies developed to reduce odors at poultry houses. When choosing a technology, it is important to consider a number of factors that affect the suitability of such a technology, including:

- smell control requirements: continuous monitoring of permissible emission levels, monitoring during unexpected, unforeseen events or adverse weather conditions;
- required level of odors control (whether a significant reduction in all emissions is required or if only a slight reduction is required);
- available funds to cover the costs of adopted additional technologies;
- configuration of a poultry processing enterprise (number of rooms with birds, as well as dimensions and their design);
- proven effectiveness and cost-effectiveness of available technologies.

For the purposes of this research, the selected technologies were grouped into the following categories:

- dry dust filtration;
- wet cleaning;
- electrostatic dust deposition;
- dust collecting structures;
- aeration of waste. [5, 6]

### Table 1. Parameters of air pollutant emissions from poultry house.

| Workshop, building | Pollutant Code | Pollutant         | Specific emission of pollutants into the atmospheric air (mg/(c*1c.l.w.)) | Pollutant Concentration (mg/m3) | Standard Value (MAC, ASEL) (mg/m3) | Perception threshold (mg/m3) |
|--------------------|----------------|------------------|--------------------------------------------------------------------------|---------------------------------|------------------------------------|-----------------------------|
| house number 1     | 0333           | dihydrosulfide   | 0.8                                                                      | 0.04                            | 10                                 | 0.014-0.03                  |
|                    | 0410           | methane          | 57.4                                                                     | 3.2                             | 7000                               | n/d                         |
|                    | 1052           | methanol         | 0.58                                                                     | 0.03                            | 15                                 | 0.03-0.05                   |
|                    | 1071           | hydroxybenzene   | 0.36                                                                     | 0.02                            | 1                                  | 0.004                       |
|                    | 1246           | ethyl formate    | 1.68                                                                     | 0.09                            | 10                                 | n/d                         |
|                    | 1314           | Propanal         | 0.67                                                                     | 0.04                            | 5                                  | n/d                         |
|                    | 1531           | hexanoic acid    | 0.75                                                                     | 0.04                            | 5                                  | 0.0001-0.00009              |
|                    | 1707           | dimethyl sulfide | 3.79                                                                     | 0.21                            | 50                                 | 0.00037                     |
|                    | 1715           | methanethiol     | 0.0072                                                                  | 0.0004                          | 0.8                                | 0.0001-0.0003               |
|                    | 1849           | methylamine      | 0.26                                                                     | 0.014                           | 1                                  | 0.5                         |
|                    | 2920           | fur dust (wool, down) | 20.7                                                              | 1.14                            | n/d                                | n/d                         |
|                    | 2920           | ammonia          | 1.5                                                                      | 0.82                            | 20                                 | 0.5-0.55                    |
|                    | 2603           | microorganisms (cells/c*1c.l.w.) | 1366                                                              | 6.20                            | n/d                                | n/d                         |

Note: n/d - lack of data on the regulation of pollutants or the perception threshold for unpleasant smelling substances.
Most of the technologies studied in this work were tested in poultry houses or other facilities for intensive keeping of animals and poultry existing abroad. Unfortunately, evidence for meaningful, scientifically justified odors or dust control is not always available in most cases.

The electrostatic particle ionization system was independently tested with the results published in peer-reviewed scientific papers and at conferences [7]. Such a system has high environmental efficiency, but is expensive to use in poultry farms.

A dry dust filter, a wet scrubber and some smell-neutralizing substances were tested by the manufacturer or independent organizations for the presence of dust and ammonia. [8]

Since continuous odor or dust control is required, such cleaning systems as a dry dust filter or wet scrubber should be considered, since the contact between the exhaust air and the filter system is controlled and the processing process is clearly defined and managed. [9]

Electrostatic particle ionization and aeration systems for waste could also be suitable in this case.

Considering dry dust filtration for purification of exhaust gases, it was determined that this method can be very efficient when working with very small particles, including nano-fiber media, which combine high performance with a long service life. Specialized filter coatings combine these advantages with additional properties such as fire resistance, static conductivity and resistance to adhesive materials.

The latest and most modern equipment MagixX&StuffNix (manufactured by Big Dutchman, Germany), designed to clean gas emissions in poultry farms and focused on combating unpleasant odors, is considered. StuffNix is an economical and efficient dry filtration system used in houses with a high concentration of dust [10].

MagixX technology (manufacturer Big Dutchman, Germany) is a wet cleaning system specially designed to remove ammonia and dust from house emissions.

The MagixX single-stage system is primarily designed to remove particulate and ammonia from the exhaust air, but not a specific smell [11].

A three-stage system is available for smell removal, which includes the stage of dust removal (wall for washing with water), the stage of purification from ammonia (acidified wall for washing) and the stage of biofiltration (vertical wall of the biofilter).

To assess the economic and environmental efficiency of the two most preferred methods of gas cleaning of emissions for poultry farms, a capital cost structure was compiled, the net annual savings were calculated based on the measured volume of emissions, as well as the percentage of efficiency of cleaning the technology from gaseous emissions. After calculating the capital and operating costs, cash flow was estimated for the MagicX wet filter installation projects and the implementation of the StuffNix dry filter installation.

After analyzing the results obtained, it can be concluded that the methods presented in this work for cleaning gas emissions to reduce odors are effective.

The results were structured in table 2, which is presented below.

| Parameters for technology benchmarking | Wet filtration system MagixX | Dry filtration system StuffNix |
|----------------------------------------|-------------------------------|--------------------------------|
| **Technical rationale**                |                               |                                |
| 1. Design Features                     |                               |                                |
| Modular design - up to 40% reduction in energy costs compared to non-modular cleaners | High storage potential due to V-shaped settling chambers outside the air stream |
| Depending on the need for ventilation, only the required number of modules is connected – reduction of operating costs | Stable flow resistance due to unobstructed airflow |
| The special order of the filter walls provides a large cleaning area - a high-performance air filter for trapping dust and ammonia | Good ability to maintain the shape of the filter walls due to geometric structures |
The filter wall is made of high quality plastic. Easy to clean, long life

Filter Service Easy service and maintenance work

Operative installation, due to the extraction of filter elements to the required sizes and their fastening; capital expenditures, operating and maintenance costs are significantly reduced compared to water-based cleaners.

Environmental rationale

| Purpose                          | Reducing odors, dust and germs | Reducing odors, dust |
|---------------------------------|--------------------------------|----------------------|
| 3.                             | Reduction of odors, dust and germs | Reduction of odors, dust |
| 4. Removing malodorous substances | 70% | 30% |
| 5. Removing dust                | 90% | 40% |

Economic rationale

| Purpose                          | Costs          | Costs          |
|---------------------------------|----------------|----------------|
| 6. Operating costs              | 21900 rbl      | 14600 rbl      |
| 7. Discounted costs over 10 years | 740 thousand rbl | 601.4 thousand rbl |
| 8. Net annual savings           | 11431.1 rbl/year | Absent         |

Thus, after a comparative analysis of the main characteristics and calculated indicators of the two technologies for cleaning off malodorous substances, namely StuffNix and Magic X, we can conclude that the Magic X technology (which is based on the wet cleaning method) shows the best ecological and economic effect.

4. Conclusion

In the research process, the main pollutants were identified, which are sources of a strong odor at poultry houses and cause many problems, both to employees of the enterprise and to people living nearby.

The paper analyzes the main technologies used to clean gas emissions at poultry houses focused on eliminating odors and also studies the international experience of designing plants for the removal of pollutants.

The feasibility of use was shown by wet and dry filtration technologies to eliminate odors and reduce dust concentration. An environmental and economic rationale is provided for choosing the benchmark or perspective technology for reducing odors in a poultry house, which is the wet cleaning method with the Magic X filtration system as an example.

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