Results of research on development of electric air ozonizer for livestock rooms

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Abstract. The greatest danger from the point of view of infection of farm animals is the air inside the production premises. One of the ways to improve performance and improve the air environment is ozonation. The article proposes the design of an autonomous module of an electric ozonator operating on the basis of a corona discharge, designed to improve the air environment and prevent the spread of contagious animal diseases. A distinctive novelty of the proposed design is the emitter module, made in the form of two ceramic bases with tungsten electrodes fixed on them, on one base in the form of a grid having a honeycomb cell shape, on the other in the form of a needle. Structurally, the emitter provides for adjusting the distance of the discharge gap between the electrodes of the emitter, which ensures the adjustment of ozone performance and increases the reliability of the ozonator as a whole. The results of experimental studies on the ozonation of the volume of the room using an autonomous module of the electric ozonizer operating on the principle of a corona discharge are presented. It has been established that the concentration of the ozone-air mixture increases with an increase in the operating voltage at the emitter electrodes and a decrease in the distance between them. The maximum performance indicators of the installation for ozone (10 mg/m³) were obtained at an operating voltage of 30 kV at the emitter and a discharge gap of 25 mm. An experiment on the effect of ozone concentration in the air on pathogenic microflora showed the effectiveness of the application to reduce pathogenic microflora in the air.

1 Introduction

For the successful development of animal husbandry as one of the leading branches of the agro-industrial complex, a constant increase in the productivity of animals (poultry) is necessary. One of the solutions to this problem was the widespread transition of keeping animals (birds) to enclosed spaces with the maintenance of optimal microclimate parameters. Modern requirements for the parameters of the air environment in agricultural premises are as follows: ionization 100·10³-480·10³ ion/cm²; qualitative composition by gas (hydrogen sulfide 5-15 mg/m³, ammonia 1-10 mg/m³, carbon dioxide up to 2.5 mg/l); suspended dust particles 0.4-1.5 mg/m³; colonies of pathogenic microflora up to 100,000 CFU/m³.

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The greatest danger from the point of view of infection of farm animals is the air inside the production premises. Therefore, the development of technological and technical solutions that ensure high quality of the air environment in production livestock buildings is relevant for agricultural production.

When regulating the quality of air gray and the sanitary condition of livestock buildings, a combination of physical and chemical methods can be used using: active ventilation, washing, aeration, disinfection and irrigation. These methods of processing livestock buildings and technological equipment have a number of significant drawbacks, which are high water consumption, high consumption of electrical energy, as well as material costs for the purchase, transportation and storage of chemical disinfectants. These disadvantages are absent when treated with an ozone-air mixture. Currently, the best option for obtaining an ozone-air mixture in large volumes is electrical synthesis, based on the dissociation of the ozone molecule under the influence of the energy of an electric discharge [1-8].

2 Materials and methods

The research methodology involved the use of patent search methods and analysis of scientific literature, the theory of electroozonization processes, methods of mathematical statistics and experiment planning in relation to electrophysical methods for improving the quality of the air in industrial premises for agricultural purposes.

For ozonation, various design schemes of electric ozonizers are used, the common nodes of which are a high voltage source, electrodes, and a fan [9–11]. The disadvantages of such designs are the low productivity of ozone and the low reliability of the electrodes.

For air ozonation, a new design of an electric corona discharge ozonizer was developed, which is an autonomous module [12].

In order to increase the productivity of ozone and improve the reliability of the electrodes, a new design of the emitter was used in the developed ozonizer. The emitter is made in the form of two ceramic bases with tungsten electrodes fixed on them.

The electrodes are located on one base in the form of a grid having a honeycomb cell shape, on the other in the form of a needle. The design of the developed emitter provides for the adjustment of the air gap between the ceramic bases and the electrodes. This provides adjustment of the ozone output of the emitter on a single high voltage source and increases the reliability of the ozone generator as a whole.

The technical characteristics of the developed ozonizer are presented in Table 1. The design diagram of the autonomous module of the electric ozonator is shown in Figure 1.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Indicator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Supply network voltage, V</td>
<td>220</td>
</tr>
<tr>
<td>Ozone concentration at the outlet of the autonomous module, mg/m³</td>
<td>0.01…10</td>
</tr>
<tr>
<td>Room volume, m³</td>
<td>up to 3600</td>
</tr>
<tr>
<td>Duration of work, h</td>
<td>0.1:0.25:0.5:1:2:4</td>
</tr>
<tr>
<td>Power consumption, W</td>
<td>500...3500</td>
</tr>
<tr>
<td>Temperature range, °C</td>
<td>-10 to +35</td>
</tr>
<tr>
<td>Operating mode</td>
<td>manual/automatic</td>
</tr>
</tbody>
</table>

The technology of air environment ozonation in livestock buildings using an autonomous module of an electric ozonizer can be implemented in various versions: the use of ozone generators in conjunction with a ventilation system; stationary location of stand-alone ozone generators in working areas; the use of autonomous ozone generators in a mobile version.
**3 Results**

Experimental substantiation of the parameters of the ozonator and the optimal modes of ozonation of the air environment using an autonomous module of the electric ozonizer was carried out using the theory of experiment planning and regression analysis [12-14].

The study of the influence of the parameters of the ozonizer on the efficiency of ozonation was carried out with the implementation of the Kono second-order plan for a 2-factor experiment. The following factors were taken as variable factors: operating voltage at the emitter electrodes (x1); distance between electrodes (x2). The ozone concentration (y) at the outlet of the ozonator was studied as a response function. The values and range of variable factors are shown in Table 2.

**Table 2. Values and range of variation of factors in coded and natural variables.**

<table>
<thead>
<tr>
<th>Factor name</th>
<th>Value in coded and natural variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating voltage at the emitter electrodes (x1), V</td>
<td>-1  10000  20000  30000</td>
</tr>
<tr>
<td>Distance between electrodes (x2), m</td>
<td>-1  0.025   0.030   0.035</td>
</tr>
</tbody>
</table>

When processing the experimental data, a regression equation was obtained for the effect of the operating voltage on the emitter electrodes (x1) and the distance between the electrodes (x2) on the ozone concentration (y). The resulting regression equation in coded variables is:
\[ y = b_0 + b_1 x_1 + b_2 x_2 + b_{12} x_1 x_2 + b_{11} x_1^2 + b_{22} x_2^2 \]  

(1)

Where \( b_0 = 1.90 \), \( b_1 = -1.45 \), \( b_2 = 3.45 \), \( b_{12} = -0.72 \), \( b_{11} = -0.24 \), \( b_{22} = 2.1 \) – regression coefficients.

The coefficients of the equation are significant, since the adequacy of the model satisfies the table value of the Fisher criterion \( (F_r = 2.95 \leq F_t = 2.96) \).

Figure 2 shows the calculated surface of the dependence of the ozone concentration on the operating voltage at the emitter electrodes and the distance between the electrodes (discharge gap) constructed according to equation (1).

![Figure 2](image)

**Fig. 2.** Dynamics of ozone concentration changes depending on the operating voltage at the emitter electrodes and the distance between the electrodes (discharge gap).

Production experiments were carried out on the effect of ozone concentration on the change in the parameters of the air environment in the room. To change the ozone concentration in the room, an autonomous module of an electric ozonizer was used. During the experiment, samples of the air environment in the room were taken before ozonation (control) and until the concentration of ozone in the air reached 1, 5, 10 mg/m³.

The results of the experiment on the effect of ozone concentration on the change in the parameters of the indoor air are presented in Table 3.

### 4 Discussion

Taking into account the surface in Figure 2, it can be noted that the ozone concentration increases with an increase in the operating voltage on the emitter electrodes and a decrease in the distance between them. This corresponds to the generally accepted laws of ozone generation in a corona discharge. According to the data obtained, for the investigated design of the autonomous module of the electric ozonator, the maximum performance indicators for ozone are 10 mg/m³. They were obtained at an operating voltage of 30 kV at the emitter and a discharge gap of 25 mm. A further increase in the operating voltage and a
The decrease in the distance between the electrodes of the emitter leads to the transition of the corona discharge into an electric one and interrupts the process of ozone formation.

**Table 3.** Results of experimental studies of the air environment.

<table>
<thead>
<tr>
<th>Name</th>
<th>View</th>
<th>Unit rev.</th>
<th>X₁</th>
<th>X₂</th>
<th>X₃</th>
<th>X₄</th>
<th>X₅p</th>
<th>HCP</th>
<th>Degree of reliability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience 1 (ozone concentration 1 mg/m³)</td>
<td>Pathogenic Staphylococcus</td>
<td>CFU/m³</td>
<td>368</td>
<td>404</td>
<td>383</td>
<td>437</td>
<td>398</td>
<td>14.95</td>
<td>398.00±14.95*</td>
</tr>
<tr>
<td>Experience 1 (ozone concentration 1 mg/m³)</td>
<td>Mold</td>
<td></td>
<td>&gt;20</td>
<td>&gt;20</td>
<td>&gt;20</td>
<td>&gt;20</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience 2 (ozone concentration 5 mg/m³)</td>
<td>Pathogenic Staphylococcus</td>
<td>CFU/m³</td>
<td>313</td>
<td>385</td>
<td>329</td>
<td>333</td>
<td>340</td>
<td>15.61</td>
<td>340.00±15.61**</td>
</tr>
<tr>
<td>Experience 2 (ozone concentration 5 mg/m³)</td>
<td>Mold</td>
<td></td>
<td></td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>&gt;10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Experience 3 (ozone concentration 10 mg/m³)</td>
<td>Pathogenic Staphylococcus</td>
<td>CFU/m³</td>
<td>15</td>
<td>5</td>
<td>18</td>
<td>38</td>
<td>19</td>
<td>6.92</td>
<td>19.00±6.92**</td>
</tr>
<tr>
<td>Experience 3 (ozone concentration 10 mg/m³)</td>
<td>Mold</td>
<td></td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>&gt;10</td>
<td>&gt;10</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>Pathogenic Staphylococcus</td>
<td>CFU/m³</td>
<td>84</td>
<td>63</td>
<td>72</td>
<td>97</td>
<td>79</td>
<td>7.38</td>
<td>79.00±7.38</td>
</tr>
<tr>
<td>Control</td>
<td>Mold</td>
<td></td>
<td>&gt;20</td>
<td>&gt;20</td>
<td>&gt;20</td>
<td>&gt;20</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: the difference is significant in relation to the control: * - p<0.05, ** – p<0.01, *** – p<0.001

The experiment (Table 3) showed a positive effect of increasing the concentration of ozone on the improvement of the air environment. With an increase in the concentration of ozone in the air of the room (1, 5 and 10 mg/m³), a decrease in the total microbial number is observed (398.00±14.95 CFU/m³; 340.00±15.61 CFU/m³; 188.00±10.36 CFU/m³), pathogenic staphylococcus (71.00±4.42 CFU/m³; 23.00±6.34 CFU/m³; 19.00±6.92 CFU/m³) and mold (>20 CFU/m³; >10 CFU/m³; >10 CFU/m³) in air.

### 5 Conclusion

The design of an autonomous module of an electric ozonizer on a corona discharge has been developed, which provides an increase in the productivity of ozone and an increase in the reliability of the electrodes. The emitter of the ozonator is made in the form of two ceramic bases with tungsten electrodes fixed on them. The electrodes are located on one base in the form of a grid having a honeycomb cell shape, on the other in the form of a needle. The design of the developed emitter provides for the adjustment of the ozone output of the emitter on a single high voltage source and increases the reliability of the ozone generator as a whole.

Experimental studies have established that the concentration of the ozone-air mixture increases with an increase in the operating voltage at the emitter electrodes and a decrease in the distance between them. The maximum performance indicators of the installation for ozone formation in a corona discharge. According to the data obtained, for the investigated needle. The design of the developed emitter provides for the adjustment of the air gap in the distance between them. This corresponds to the generally accepted laws of ozone generation in air.

An experiment on the effect of ozone concentration in the air on pathogenic microflora showed the effectiveness of the application to reduce pathogenic microflora in the air. With an increase in the concentration of ozone in the air of the room (1, 5 and 10 mg/m³), a decrease in the total microbial number is observed (398.00±14.95 CFU/m³; 340.00±15.61 CFU/m³; 188.00±10.36 CFU/m³), pathogenic staphylococcus (71.00±4.42 CFU/m³; 23.00±6.34 CFU/m³; 19.00±6.92 CFU/m³) and mold (>20 CFU/m³; >10 CFU/m³; >10 CFU/m³) in air.
23.00±6.34 CFU/m$^3$; 19.00±6.92 CFU/m$^3$) and mold (>20 CFU/m$^3$; >10 CFU/m$^3$; >10 CFU/m$^3$).

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