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Investigation of microclimate parameters for the content of toxic gases in poultry houses during air treatment in the scrubber with the use of various fillers

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To reduce the content of toxic gases in the emissions of poultry farms, top-priority goal in the system of sanitary and medical and preventive measures is the implementation of a set of measures aimed at reducing the emissions of pollutants into the atmospheric air with the use of scrubbers. The purpose of scientific and economic experiments was to study of microclimate parameters for the content of toxic gases in poultry houses during air treatment in the scrubber with the use of various fillers. The experiments were carried out in an industrial poultry house for egg-laying hens measuring 18 × 96 m, fitted with 4-tier 'Hellmann' cage batteries with a belt litter removal system and integrated air ducts. The capacity of the poultry house was 47280 laying hens. In a scrubber, Zeolite, Phosphogypsum, Zeolite with iron sulfate and Zeolite with aluminum chloride in a ratio of 1:1 were used as fillers during three consecutive litter cleaning cycles. The total amount of adsorbent or reagent loaded into the scrubber was 150 ± 0.5 kg. The scrubber was reloaded once every seven days. A poultry house with a standard air mixing unit was used as a control. The amount of contaminated air supplied through a scrubber ranged from 10 to 15 thousand m^3/h. Analyzing the results of studies of the use of various substances or mixtures in the scrubber, we can note that the use of a mixture of Zeolite and aluminum chloride in a ratio of 1:1 in the calculation of 150 ± 0.5 kg of the mixture at 15 thousand m^3/h of polluted air provided the greatest reduction in ammonia content (up to 6.3 ± 0.55 mg/m^3) in the air during the 7 days of accumulation of litter. Somewhat worse results (up to 9.1 ± 0.46 mg/m^3 on the 7th day) were obtained by applying a mixture of Zeolite and iron sulfate, and the worst results - with Zeolite (up to 15.1 ± 0.63 mg/m3 with a control of 15.1 ± 0.47 mg/m^3). At the same time, the use of all selected substances ensured not exceeding the maximum permissible concentration of ammonia in the air (15 mg/m^3) during the first 5 days. Therefore, the choice of a particular substance should first of all be based on the price affordability of a reagent, and in conditions of the equivalence – to choose a more effective reagent. The technological methods of improvement of microclimate in poultry houses for the maintenance of hens in the cage batteries with a belt litter removal system by reducing the content of ammonia in the air have been scientifically substantiated. It was established that the transmission of the polluted air through a scrubber with Phosphogypsum, a mixture of Zeolite and iron sulfate, Zeolite and aluminum chloride provides a decrease in the content of ammonia in the air of the poultry house, by 2.0-1.4; 3.2-1.7 and 4.9-2.5 times, respectively; while worked out fillers (Zeolite, Phosphogypsum, Zeolite+iron sulfate (1:1), Zeolite+aluminum chloride (1:1)) contained from 4.37% to 14.51% of nitrogen.
Keywords: Toxic gases; poultry house; ventilation; scrubber; microclimate; cage battery; chicken litter; ammonia; adsorbent; air treatment

Introduction

At present, most enterprises of various industries turn out to be sources of environmental pollution, and the main objective of environmental measures implemented at enterprises is to minimize possible emissions to the atmosphere.

It is known that ventilation emissions of poultry houses into the atmosphere and litter during its storage, processing and use as fertilizers are essential factors of environmental pollution (Dunlop et al., 2016).

According to the results of the surveys of many poultry farms in different regions (Calvet et al., 2011; Xin et al., 2011), one of the main causes of ecological danger from the accumulation of litter is the poor quality of processing operations for the removal of litter from poultry houses, as well its improper storage, transportation and use of it as an organic component in the production of fertilizers.

The unsatisfactory storage and use of litter does not only cause significant damage to the environment, resulting in poor ecological conditions in the poultry farms, but also leads to the loss of a huge amount of quality organic fertilizer necessary for agricultural land (Mendes et al., 2014).
Ammonia from the ventilations emissions, reacting with acidic compounds of the atmosphere, and then falling along with precipitation to the ground, is the main cause of acidification of soils. This phenomenon can affect both the presence in the soil of substances necessary for plant growth, and toxic elements. Along with this, ammonia contributes to the enrichment of nitrogen from poor soil nutrients, which upset the balance of sensitive ecosystems, causing either increased growth or the disappearance of certain plant species. Ammonia can also have a direct negative effect on plants, damaging leaves and slowing their growth (Casey et al., 2008; Nahm, 2005; Fernanda et al., 2017).
Carbon dioxide emissions contribute to increasing of its content in the atmosphere, which is one of the causes of the greenhouse effect and the overall warming of the climate.
Thus, the study and analysis of scientific and technical literature shows that a lot of attention is now given to the improvement of microclimate in poultry houses, as a factor contributing to the improvement of the preservation and productive parameters of poultry, the reduction of the negative impact on the health of the workers of the poultry enterprises and the environment. Significant influence on the microclimate of poultry houses, in particular on such parameters as the content of harmful gases in the air of the poultry houses, microbial contamination of the air, is caused by the poultry litter during its temporary storage in the poultry houses. The conditions for the temporary storage of the litter in the poultry houses, in turn, have a significant impact on the moisture content of the poultry litter, the loss of its main nutrients, its value as a raw material for further processing and the cost of processing.
A number of scientists and experts point out (Gates et al., 2009; Broucek & Bohuslav, 2015; Lima et al., 2011; Osorio et al., 2013; Al-Homidan et al., 2003; Miles et al., 2011; Costa et al., 2012), that it is necessary to take measures to minimize the mentioned hazards starting from the poultry houses. At the same time, the development of effective and safe ways to reduce the negative impact of poisoning on the microclimate of poultry houses and toxic emissions into the atmosphere requires conducting relevant research, in particular, regarding cage poultry keeping with modern equipment, which involves a fairly long accumulation of litter in the premises on the belt conveyor systems deleting it (up to 7 days). Issues that are still insufficiently studied include the impact of the accumulation of litter on the microclimate in the poultry houses and changes in the composition of the product itself. The methods and technological regimes for the reduction of toxic gas emissions in the poultry houses and the decontamination of microorganisms are required to be worked out. On the other hand, the reduction of the losses of the main nutrients of the litter, which characterize its value as raw materials for processing, or as fertilizers, obtaining already in the poultry of raw materials prepared for processing by appropriate methods, reducing the costs of transportation and processing of litter should be the objectives of these scientific studies.
During the years of the independence, a number of legislative acts aimed at protecting the environment, including the pollution with gaseous emissions, liquid and solid waste from livestock enterprises, were adopted in Ukraine. First of all, it is the Law of Ukraine ‘On Environmental Protection’ (1991), the Law of Ukraine ‘On Ensuring the Sanitary and Epidemiological Well-being of the Population’ (1994), the Law of Ukraine ‘On the Protection of Atmospheric Air’ (1992). In 2000, the National Action Plan on Environmental Hygiene was approved by the Cabinet of Ministers of Ukraine on October 13, 2000, No. 1556-2000-п, by means of which it is planned to implement a number of measures to reduce environmental pollution.
In addition, various programs of action for the protection of the environment are developed, which include measures to reduce the negative impact on the natural environment, which leads to an improvement in the socio-economic status of the population. Only at the expense of the introduction of resource-saving and low-waste technologies, as well as environmental protection measures it is possible to preserve the equilibrium state of the environment.
Therefore, the development of effective technical solutions and technological methods for reducing emissions of toxic gases, dust and microorganisms could be a significant contribution to solving this problem.

Materials and methods

The experiments were carried out in an industrial poultry house for egg-laying hens measuring 18×96 m, fitted with 4-tier ‘Hellmann’ cage batteries with a belt litter removal system and integrated air ducts. The capacity of the poultry house was 47280 laying hens. The scrubber was installed against the air duct, which supplied the air from the poultry house into the air mixer chamber (Figure 1).

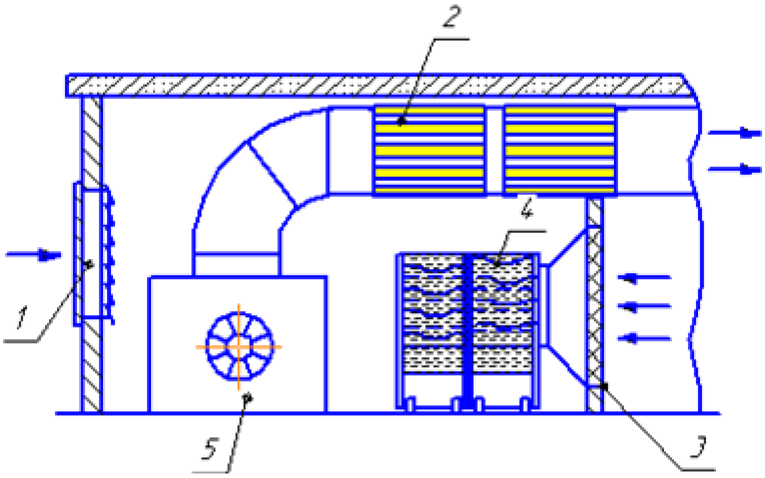

Figure 1. Scrubber placement scheme:1 – shutter of fresh air supply, 2 – bactericidal device, 3 – valve for supply of polluted air from the poultry house, 4 – scrubber, 5 – air supply fan in the built in ducts of cage batteries.

In a scrubber, Zeolite, Phosphogypsum, Zeolite with iron sulfate and Zeolite with aluminum chloride in a ratio of 1:1 were used as fillers during three consecutive litter cleaning cycles. The total amount of adsorbent or reagent loaded into the scrubber was 150 ± 0.5 kg. The scrubber was reloaded once every seven days. A poultry house with a standard air mixing unit was used as a control. The amount of contaminated air supplied through a scrubber ranged from 10 to 15 thousand m^3/h.
The parameters of the microclimate (temperature and relative humidity of the air, the content of ammonia, hydrogen sulfide and carbon dioxide in it) were determined once a day at one and the same time, from 9 to 11 o'clock, by the standardized methods in 3 different points along the diagonal of the poultry house (at the beginning, in the middle and at the end of its cage part) at the level of the first and fourth tiers of the cage batteries.
The temperature and relative humidity of the air were measured using the aspiration psychrometer MB-4M. The content of ammonia, carbon dioxide, hydrogen sulfide was determined using the universal gas analyzer UG-2. Statistical processing of research results was performed according to generally accepted methods, using software applications for Windows OS: Microsoft Excel.
The probability of the results obtained and the difference between the groups were calculated by the formula:

$$t_d = \frac{M_1 - M_2}{\sqrt{m_1^2 + m_2^2}},$$

Where, t_d - Student's t-test; M_1 i M_2 - the arithmetic mean of the parameter in the groups that were compared; ± m - statistical error of the arithmetic mean of the parameter.

Results and discussion

The results of studying the effect of the air treatment in a scrubber using different fillers on the content of toxic gases in the air of the poultry house are given in Tables 1-4.

Table 1. The effect of the air treatment in a scrubber on the content of toxic gases in the air using Zeolite as a filler.

Microclimate parameter	Unit of measurement	Days of the accumulation of litter on the cage battery belts			
		1	3	5	7
Experiment (Zeolite 150 kg)					
Ammonia content in the air	mg/m^3	6.3 ± 0.43*	10.7 ± 0.43	13.7 ± 0.47	15.1 ± 0.63
Carbon dioxide content in the air	%	0.09	0.09	0.1	0.11
Control					
Ammonia content in the air	mg/m^3	8.4 ± 0.47	11.1 ± 0.68	13.8 ± 0.48	15.1 ± 0.47
Carbon dioxide content in the air	%	0.1	0.09	0.11	0.12

Note: * - P<0.05 in comparison with the control

As the study showed, on the first day of the operation of the scrubber passing the air through the cassettes with Zeolite allowed to reduce the content of ammonia in the air of the poultry house by 1.3 times (from 8.4 ± 0.47 to 6.3 ± 0.43 mg/m^3). In the future, the efficiency of the scrubber was rapidly reduced; and from the third day the decrease in ammonia content in the air of the experimental poultry house was insignificant (up to 15.1 ± 0.63 mg/m^3 on the 7th day). Other parameters of the microclimate (the content of carbon dioxide and hydrogen sulfide in the air) did not affect the air treatment in the scrubber.
The duration of the effective action of this adsorbent (Zeolite) can undoubtedly be increased by increasing its amount, but at the same time it will increase the cost, and hence the cost of the adsorbent and the operating costs in general.

Table 2. The effect of the air treatment in a scrubber on the content of toxic gases in the air using Phosphogypsum as a filler.

Microclimate parameter	Unit of measurement	Days of the accumulation of litter on the cage battery belts			
		1	3	5	7
Experiment (Phosphogypsum 150 kg)					
Ammonia content in the air	mg/m^3	4.4 ± 0.38***	6.1 ± 0.52***	8.2 ± 0.44***	10.5 ± 0.41***
Carbon dioxide content in the air	%	0,10	0,12	0,11	0,13
Control					
Ammonia content in the air	mg/m^3	8.9 ± 0.43	11.3 ± 0.49	13.9 ± 0.66	15.2 ± 0.44
Carbon dioxide content in the air	%	0.11	0.12	0.12	0.12

Note: *** - P<0,001 in comparison with the control.

The air treatment of a poultry house in a scrubber filled with Phosphogypsum contributed to a decrease in the content of ammonia in the air on the first day by 2.0 times (from 8.9 ± 0.43 to 4.4 ± 0.38 mg/m^3), but in the future, the effectiveness of the air purification also decreased, and on the 7th day the concentration of ammonia in experimental poultry house was less than by 1.4 times (from 15.2 ± 0.44 to 10.5 ± 0.41 mg/m^3). Other parameters of the microclimate (the content of carbon dioxide and hydrogen sulfide in the air) also were not significantly affected with the treatment of the air by passing it through a scrubber with Phosphogypsum.

Table 3. The effect of the air treatment in a scrubber on the content of toxic gases in the air using a mixture of Zeolite with iron sulfate (1:1) as a filler.

Microclimate parameter	Unit of measurement	Days of the accumulation of litter on the cage battery belts			
		1	3	5	7
Experiment (Zeolite 75 kg+iron sulfate 75 kg)					
Ammonia content in the air	mg/m^3	2.5 ± 0.34***	3.8 ± 0.46***	5.9 ± 0.52***	9.1 ± 0.46***
Carbon dioxide content in the air	%	0.09	0.1	0.11	0.11
Control					
Ammonia content in the air	mg/m^3	8.1 ± 0.35	10.2 ± 0.51	13.0 ± 0.55	15.1 ± 0.63
Carbon dioxide content in the air	%	0.08	0.09	0.11	0.12

Note: *** - P<0,001 in comparison with the control

With the use of a mixture of Zeolite with iron sulfate as a filler in a scrubber, the ammonia content in the air of the experimental poultry house was reduced by 3.2 times compared with the control poultry house on the first day (from 8.1 ± 0.35 to 2.5 ± 0.34 mg/m^3) and (from 15.1 ± 0.63 to 9.1 ± 0.46 mg/m^3) on the 7th day.

Table 4. The effect of the air treatment in a scrubber on the content of toxic gases in the air using a mixture of Zeolite with aluminium chloride (1:1) as a filler.

Microclimate parameter	Unit of measurement	Days of the accumulation of litter on the cage battery belts			
		1	3	5	7
Experiment (Zeolite 75 kg+$AlCl_3$ 75 kg)					
Ammonia content in the air	mg/m^3	1.7 ± 0.23***	2.8 ± 0.42***	4.3 ± 0.50***	6.3 ± 0.55***
Carbon dioxide content in the air	%	0.07	0.09	0.1	0.11
Control					
Ammonia content in the air	mg/m^3	8.4 ± 0.41	10.5 ± 0.45	13.2 ± 0.49	15.9 ± 0.54
Carbon dioxide content in the air	%	0.07	0.09	0.11	0.12

Note: *** - P<0.001 in comparison with the control.

A mixture of Zeolite and aluminium chloride provided the reduction in the concentration of ammonia in the air of the poultry house: by 4.9 times (from 8.4 ± 0.41 to 1.7 ± 0.23 mg/m^3) on the first day of the use of the filler, and by 2.5 times (from 15.9 ± 0.54 to 6.3 ± 0.55 mg/m^3) on the 7th day. At the same time, like the rest of the reagents, this mixture did not significantly affect the content of other toxic gases in the air (carbon dioxide and hydrogen sulfide). The dynamics of ammonia content in the air of the poultry house, depending on the substances used in the scrubber is presented in Figure 2.

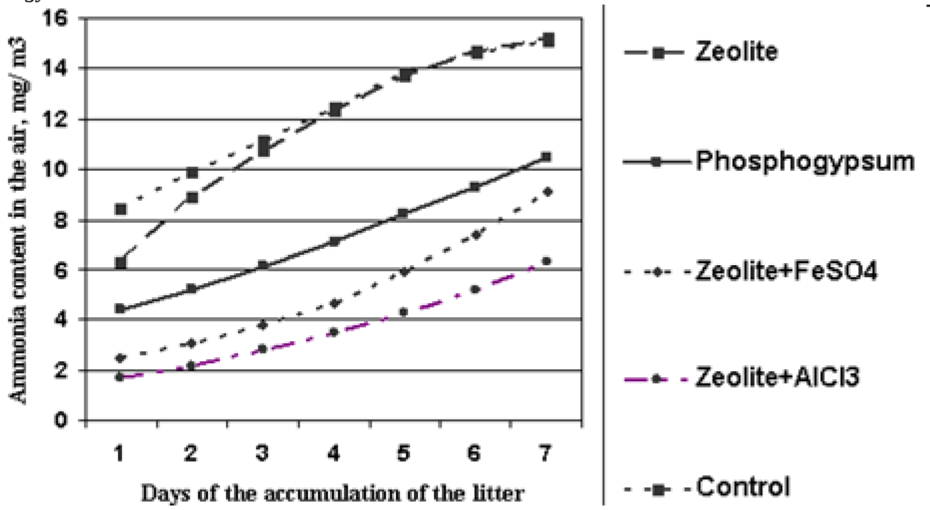

Figure 2. Dynamics of ammonia content in the air of the poultry house, depending on the substances used in the scrubber.

Analyzing the results of studies of the use of various substances or mixtures in the scrubber, we can note that the use of a mixture of Zeolite and aluminum chloride in a ratio of 1:1 in the calculation of 150 ± 0.5 kg of the mixture at 15 thousand m^3/h of polluted air provided the greatest reduction in ammonia content (up to 6.3 ± 0.55 mg/m^3) in the air during the 7 days of accumulation of litter. Somewhat worse results (up to 9.1 ± 0.46 mg/m^3 on the 7th day) were obtained by applying a mixture of Zeolite and iron sulfate, and the worst results - with Zeolite (up to 15.1 ± 0.63 mg/m^3 with a control of 15.1 ± 0.47 mg/m^3). At the same time, the use of all selected substances ensured not exceeding the maximum permissible concentration of ammonia in the air (15 mg/m^3) during the first 5 days. Therefore, the choice of a particular substance should first of all be based on the price affordability of a reagent, and in conditions of the equivalence it is expedient to choose a more effective reagent. After seven days of use, the samples of the substance in a scrubber were taken for chemical analysis of nitrogen content. The results of these analyzes are given in Table 5.

Table 5. Nitrogen content in the active substance of a scrubber after 7 days of its use.

The name of the substance	Total nitrogen content, %
Zeolite	4.37 ± 0.024
Phosphogypsum	10.12 ± 0.036
Zeolite+iron sulfate (1:1)	8.73 ± 0.041
Zeolite+aluminium chloride (1:1)	14.51 ± 0.052

As can be seen from the table, the worked out fillers contain from 4.37% to 14.51% of nitrogen, that is, they can be used as a fertilizer or added to the litter for its composting. Thus, irreversible losses of ammonia nitrogen can be prevented, and instead of polluting the environment, this nitrogen can be rationally used in the cultivation of crops.

Analyzing the results of the studies on the use of various substances or mixtures in a scrubber, it can be noted that although their effectiveness in reducing the ammonia content in the air of the poultry house was different, the use of all selected substances provided the ammonia content in the air lower than the maximum permissible concentration for the first 5 days. In our opinion, the choice of a substance should, first of all, be based on the price affordability of a reagent, and in conditions of equivalence it is necessary to choose a more effective reagent.

According to the studies conducted in the former Soviet republics countries and the countries outside the former Soviet Union (Burns et al., 2007; Calvet et al., 2010; Naseem & King, 2018; Zhao et al., 2015), the content of ammonia in large poultry farms varies within 0.3-1.42 mg/m^3. At a distance of 500, 1000, 1500 and 2000 m, the ammonia content is reduced by 40%, 29%, 28% and 24%, respectively. The maximum one-time concentrations of hydrogen sulfide in the poultry farms and beyond their limits exceed the allowable level by 1.5-6.3 times. In the air at a distance of 500, 1000, 1500 and 2000 m from poultry farms, the concentration of microbial bodies in 1 m^3 of air decreased accordingly by 53%, 51%, 50% and 48%. The results of the research have shown that within the population living in the area of the placement of poultry farms (including children) an increased level of morbidity associated with respiratory organs, infectious and parasitic diseases, and diseases of the digestive system was manifested (Donham et al., 2002).

In other studies, it was found that the concentration of ammonia in the investigated poultry farm was higher than the maximum permissible concentration in the breeding department of young animals and in the premises for adult birds. Hydrogen sulfide in premises of industrial premises with daily mechanical cleaning of the suction was found in concentrations up to 6.0 mg/m^3. Bacterial flora in the air samples is presented by conventionally pathogenic microorganisms (golden and white staphylococci, hemolytic streptococcus, sticks of the proteins and intestinal groups), saprophytes (gram-positive spore sticks). Along with this, pathogenic forms of the intestinal group - pathogens colienteritis, as well as anthropozoonosis, in particular, ornithosis, toxoplasmosis, chlamydia and other infectious diseases. In microbial aerosol, the bulk of the bacteria - 82-89%, mushrooms - 11-17.5% and actinomycetes - 0.5% were also found. The dust on the poultry farm is mixed, organic and contains 3-6% of fiber, up to 70% of crude protein, 7-10% of ether extracted substances, feathers, fluff, litter particles, fungi and microbes (Casey et al., 2010; Osorio et al., 2015; Neila et al., 2016; Kiis, 2016).

In studies conducted at the Ukrainian Research Institute, the microflora was recorded at a distance of up to 500 m from the poultry house (Tihonchuk, 2015).

Based on the analysis of the results of tests with a scrubber in which various fillers were used, Phosphogypsum was chosen as the cheapest, affordable and sufficiently effective reagent. Although somewhat worse results were produced using Phosphogypsum in terms of reducing the content of toxic gases in the air, in particular - ammonia (up to 10.5+0.41 mg/m^3 on the 7th day) than when using mixtures of Zeolite with iron sulfate (up to 9.1+0.46 mg/m^3 on the 7th day) and Zeolite with aluminum chloride (up to 6.3+0.55 mg/m^3 on the 7th day), at the same time, this reagent provided a significant reduction the content of ammonia in the air during the first 5 days of accumulation of litter (up to 8.2+0.44 mg/m^3). When choosing this substance, we also took into account its large reserves in Ukraine, low prices and environmental safety. This does not preclude, in our opinion, the use of other reagents in a scrubber.

Conclusion

Techniques for improving the microclimate in poultry houses to keep laying hens in cage batteries with a belt removal system in combination with methods aimed at reducing the content of ammonia in the air have been scientifically substantiated. The passage of contaminated air through a scrubber with Phosphogypsum, a mixture of Zeolite and iron sulfate, Zeolite and aluminum chloride provides a decrease in the ammonia content in the air of the poultry house by 2.0-1.4; 3.2-1.7 and 4.9-2.5 times, respectively. It has been determined that worked-out fillers (Zeolite, Phosphogypsum, Zeolite+iron sulfate (1:1), Zeolite+aluminium chloride (1:1)) contained from 4.37% to 14.51% of Nitrogen.

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