Improving the Technology of Dust Deposition from the Air of Livestock Premises Using an Electrostatic Precipitator

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Abstract. This paper provides recommendations based on calculations of the consistent placement of dust separating devices for treating air of livestock premises. This study is relevant due to the fact the atmospheric air and, specifically, the air of livestock premises, always contains a certain amount of dust. Dust accumulation in the air of livestock premises is associated with foddering, premise cleaning, animal cleaning, and animal bedding laying. Dust content in the air livestock premises fluctuates during the day depending on the livestock and poultry foddering and feeding system, ventilation, as well as the manure removal method. From a hygienic standpoint, dust affects the animal organism directly and indirectly. The indirect effect of dusty air is associated with moisture droplets depositing on dust particles and creating fogs. Dust and fog absorb a significant part of solar radiation and worsen the photoclimate, while a layer of dust and soot settling on the windows of livestock premises reduces the natural illumination of the latter. The atmospheric air and the air of livestock premises contain various microorganisms along with dust and smoke. There is a direct relationship between dust content and the number of microorganisms since they usually settle on dust particles.

1. Introduction

The atmospheric air and, specifically, the air of livestock premises, always contains a certain amount of dust. Dust accumulation in the air of livestock premises is associated with foddering, premise cleaning, animal cleaning, and animal bedding laying. Dust content in the air livestock premises fluctuates during the day depending on the livestock and poultry foddering and feeding system, ventilation, as well as the manure removal method.

According to S.I. Plyashchenko, a pig-breeding farm with 108 thousand 1-year old heads releases dust with ventilation air up to 12-15 kg/h and more (or up to 360 kg per day), while a farm with 10 thousand 1-year old heads of young cattle — up to 6-10 kg/h (up to 240 kg per day). The permissible value of dust content in livestock premises shall not exceed 15 mg/m³. Dust direct affects the skin, mucous membranes of eyes and the respiratory tract. Dust particles mixed with sweat, fat, hair and skin debris clog skin pores, cause irritation, itching and inflammation. As a result, the thermoregulatory, excretory, protective and tactile functions of the skin are disrupted. Dust covered
Skin loses sensitivity to irritants slowing down reflex reactions. Dust clogs excretory ducts of the sweat and sebaceous glands making the skin dry, stiff and more exposed to mechanical damage. Skin integrity damage opens gates for infections. Clogging of sebaceous gland openings can cause follicular dermatitis, as well as pyoderma development if complicated by pyogenic cocci. If sheep are considered, dust contaminates their wool reducing its commercial properties. Getting into the eye mucous, dust contributes to the development of conjunctivitis and keratitis. Dust greatly affects on the respiratory tract. Dust particles exceeding 10 microns are 100% entrapped in the upper respiratory tract, while particles of 10 to 5 microns in size — in the nasal tracts. While particles smaller than 5 microns get into the lungs.

The main obstacles to dust are nasal passages, nasopharynx, trachea, large and medium bronchi. Dust in large quantities can cause hyperemia and catarrhal inflammation of the nasal mucosa, which enhances pathogenic microflora growth. Accumulating in the trachea and bronchi, dust hinders the functioning of ciliated epithelium and covers the mucous membrane with a viscous film. This causes acute and chronic catarrh of the upper and middle bronchi. Some types of flower dust can also cause allergic reactions. The dust settled in bronchi is gradually removed from them due to movement of the ciliated epithelium, dissolves in bronchial and tracheal mucus, undergoes phagocytosis, and is released when coughing. Therefore, coarse dust particles exceeding 20 microns in size have a lesser impact in hygienic terms than fine particles that reach deep into the respiratory tract.

Indoor air has favorable conditions for the accumulation and preservation of microorganisms, especially if the sanitary and hygienic standards for livestock management are not observed. The effect of microflora on the animal organism is determined by microflora type, pathogenicity, virulence, resistance, as well as the conditions in which livestock is kept. Since the volume of air in livestock premises is usually limited and ultraviolet exposure is almost absent, microflora can persist for a long time. A particularly large number of pathogenic microorganisms is observed in the livestock accommodation area.

Poor sanitation contributes to the preservation of microflora. Bacteria content in the indoor air increases 2–3-fold with the air temperature rising from 0 to 10 °C. With higher temperatures (10–25 °C), the number of microorganisms increases 5-fold or more. Bacteria's ability to reproduce grows as air humidity increases. Dry air (with 40-60% relative humidity) makes some the microorganisms die or their development is inhibited. According to F. G. Torpakov, the heated stagnant air of pig-breeding premises contains up to 1 million microbes per 1 m³. The same premises having satisfactory ventilation (35 m³/h per 1 quintal of pig weight) contain 3-5 times fewer microbes. Most of the microorganisms in closed livestock premises are saprophytes. However, among them are certain pathogens including numerous fungi and cocci posing a threat to weakened animal organisms [4].

There were cases when the pathogenic microflora of indoor air contained Pseudomonas aeruginosa, staphylococci, streptococci, tuberculosis, erysipelas and tetanus bacillus, anthrax spores, etc. Bacteria and virus carriers present in the air create a suitable environment for pathogens of paratuberculosis, paratyphoid fever, brucellosis, pasteurellosis, contagious aphtha, swine fever, etc.

Sources of pathogenic bacteria and viruses in the indoor air are animals sick with infectious diseases, as well as latent bacilli and virus carriers and bacilli emitters. If infected animals are present, the decease can spread airborne with dust and liquid droplets. Dried secretions of sick animals rise into the air as dust particles with microbes on them and can be inhaled by healthy animals. However, compared to droplet transmission, this route of transmission is less dangerous, since drying quickly kills most pathogens, except for pathogens more resistant to physical effects. Infected dust can spread anthrax, tuberculosis, sheep pox, etc.

Healthy animals are infected via droplet transmission as infected phlegm, nasal mucus and saliva are released into the air by sick animals hum, cough, or snort. Particles of plant and animal origin that carry microbes are almost completely entrapped in the upper respiratory tract. Microbes found on fine dust particles or droplets may enter the alveoli. They undergo phagocytosis and bactericidal effects of mucus and can be expectorated with coughing due to ciliated epithelium action. When the dust is swallowed, the microflora enters the stomach and is exposed to gastric acid. Mucous membrane
Lesions of the respiratory tract and lungs contribute to the rapid proliferation of microflora in the blood and the development of infectious diseases.

All the considered points state an urgent need to develop effective ways to combat dust and microorganisms that settle on it. This is the main objective of the current research.

2. Methods

Air dustiness is characterized by the amount of contained dust and dust dispersion. Air dustiness and microbiological contamination are determined by the sedimentation method. Dust content is determined by collecting the dust on a certain surface (usually sticky) by natural deposition, followed by using the counter developed by V.M. Maktusevich. The studies were carried out in various types of premises to determine premises with the highest dust content, as well as the most favorable period of the year. The collected data are shown in Table 1.

**Table 1.** Actual dust content in livestock premises.

| Premise designation                      | Dust content, mg/m³ |
|------------------------------------------|---------------------|
|                                          | winter   | summer  |
| For cattle:                              |          |         |
| tie and loose housing                    | 1.5      | 1.9     |
| on a deep bedding                        | 1.8      | 0.7     |
| calving pen and disease prevention house | 0.9      | 1.7     |
| calf shed                                | 1.2      | 1.7     |
| For pigs:                                |          |         |
| boars and pregnant sows                  | 0.8      | 1.2     |
| fattening stock                          | -        | -       |
| replacements                             | -        | 1.7     |
| For sheep:                               |          |         |
| ewes and rams                            | 2.9      | 2.9     |
| growing stock                            | 0.3      | 1.8     |
| For horses                               |          |         |
| For poultry:                             |          |         |
| adult hens                               |          |         |
| aged chickens, days                      | -        | -       |
| 1-30                                     | 1.7      | -       |
| 31-60                                    | 1.7      | 2.8     |

The Koch method was used to determine microbiological contamination, which is based on the ability of microorganisms to settle on the nutrient medium (in open Petri dishes) due to air movement (together with dust particles and aerosol droplets). The collected data are presented in Table 2.
### Table 2. Content of microorganisms in the tie calf housing air.

| Period of the year | Studied subjects   | Content of microorganisms per 1 liter of air |
|-------------------|--------------------|---------------------------------------------|
|                   |                    | total | sanitary indicative | colibacillus | hemolytic cocci |
| autumn            | disease prevention house | 249.8 | 6.5                 | 1.6          |
|                   | calf shed          | 6888.0| 8.0                 | 3.1          |
| spring            | disease prevention house | 680.6 | 5.8                 | 2.5          |
|                   | calf shed          | 902.7 | 4.3                 | 2.7          |
| winter            | disease prevention house | 118.7 | 5.5                 | 2.9          |
|                   | calf shed          | 644.5 | 3.6                 | 3.6          |

General dilution ventilation systems are most often recommended to improve the air quality of the livestock farm premises. The authors conducted several studies using this system to assess the dust content reduction in the air of the considered premises. Still, the studies have shown that mechanical air filtering (bag filters, cyclones) is ineffective if used exclusively. Increased air exchange rates also do not solve the problem. Let us substantiate this assumption by considering the following dust removal system scheme (Figure 1).

**Figure 1.** Dust extraction system scheme: 1 — dust sources; 2 — enclosed premise.

### 3. Results

Analysis of the presented scheme allows to conclude the dust content in the air of livestock premises can be reduced to established values only by increasing the air exchange rate and reducing the dust content in the supply air. In case of an ineffective dust removal system, all exhaust air containing dust will be returned back indoors with supply air.
Dust content in the supply air with a dust filter in action can be determined by the formula

\[ a_1 = a_x (1 - \eta) \]  

where \( a_1 \) is the concentration of dust entering the room with the supply air (at dust filter outlet), g/m\(^3\); 
\( \eta \) is the dust filter efficiency; 
\( a_x \) is the concentration of dust entering the dust filter with the supply air, g/m\(^3\).

Empirical research [3] shows that the most effective dust filters at enterprises are electrostatic precipitators with efficiency reaching 99%. With an electrostatic precipitator installed in the air conditioning system for supply air treatment, the dust removal process flow will be as shown in Figure 2.

**Figure 2.** Upgraded dust removal system scheme: 1 – multicyclone; 2 – inlet section; 3 – humidifying section; 4 – mixing section; 5 – air heating section; 6 – ventilation unit; 7 – junction box; 8 – air dampers section; 9 – inlet section; 10 – electrostatic precipitators.

While increasing the total airflow rate with an efficient dust removal system implemented allows to reduce the dust content in the indoor air even more, nevertheless, the air exchange rate should stay within acceptable limits according to [1] and is determined by the expression

\[ i = \frac{Q_{\text{total}}}{V_p} \leq i_r \]  

where \( i \) is the actual air exchange rate, ac/h; 
\( i_r \) – is the established air exchange rate (ac/h in livestock farm premises); \( i_r = 1.5 \) (1 ac/h, for livestock premises) [5]; 
\( V_p \) – is the internal volume of all premises, m\(^3\); 
\( Q_{\text{total}} \) – total air flow, m\(^3\)/h.

Therefore, all livestock enterprises with an air exchange rate exceeding the established values shall be provided with air units supplying air purified in dust filters to ensure an adequate supply of air into the premises.

In this case, the required number of air supply units with dust filters can be determined by the formula
\[ n = \frac{Q_{\text{total}} - l_p V_p}{Q_{\text{supply}}} \] (3)

where \( Q_{\text{supr.}} \) is the air flow per one air supply unit with a dust filter, m³/h.

4. Conclusion

Using the obtained data and specified formulas, an optimal location of the air supply unit with an electrostatic precipitator in the livestock farm can be determined (shown in Figure 3).

![Figure 3. Optimal location of the air supply unit with an electrostatic precipitator: 1 – grain processing equipment; 2 – dust exhaustion devices; 3 – electrostatic precipitator; 4 – exhaust units located in "dead zones".]

The optimal location of the air supply unit with electrostatic precipitators proposed by the authors will help to reduce dust content and improve the sanitary condition of the air of livestock premises.

Based on the abovementioned and taking into account that the sources of microbial and dust pollution of air are dried droppings, feed, bedding, droplets of saliva and mucus, insufficient air exchange, crowded conditions, dry cleaning of premises and their bad sanitary condition, the air pollution by microorganisms can be effectively reduced by creating protective green spaces around livestock farms, as well as strengthening the soil on the territory of livestock farms by sowing perennial grasses. It is also recommended to provide land reclamation for manure storage and treatment plants by planting shrubs and trees. Mealy feed shall be given to livestock in a moist form.

5. References

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