Substantiation of reducing gas emissions from industrial wastewater treatment plants of a fish plant

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Abstract. The release of foul-smelling substances polluting the atmosphere from animal husbandry complexes, facilities for processing agricultural products (animal raw materials and aquaculture), as well as from treatment facilities of the listed facilities is a discussed topic among specialists and the media since it turns out to be the cause of complaints from the population living in the immediate area. Based on a brief literature review of scientific works on topics related to gaseous emissions from livestock and poultry complexes, experimental studies were carried out to substantiate the reduction of gas emissions based on determining the quantitative and qualitative compositions and components of the gas-air mixture above the surface of the waste liquid in the sewage treatment facilities of the fish plant. Based on the results obtained, a technology based on sorption purification was proposed to reduce the number of emissions. The use of natural materials is proposed as a sorbent, which is a major benefit.

1. Introduction

The dynamic development of livestock enterprises, as well as enterprises for the processing of related products (meat and aquaculture products) on the territory of the Russian Federation, is a positive factor in the development of the agricultural and food industry. At the same time, this carries several problems, the most critical of which is the allocation of foul-smelling emissions that affect the environmental situation in the area where these enterprises are located. Such emissions have a negative impact on the health and well-being of the local population living in the immediate vicinity. Proceeding from this, many similar objects on the territory of the Russian Federation are regularly subject to inspections and related fines, as well as restrictions by supervisory authorities [1-3].

According to regulatory documents, the size of the sanitary protection zone (according to the Sanitary Rules and Norms of the Russian Federation 2.2.1 / 2.1.1.1200-03 [1, 2], the distance from the populated areas to the boundaries of industrial livestock facilities is at least 1000 meters, from the open type surface runoff treatment facilities is not less than 100 m. However, it is worth considering that depending on weather conditions and the direction of the wind, unpleasant odors can be felt at a distance of more than 5 kilometers.

The purpose of the study in this work is to develop and substantiate a method for reducing the technogenic load on the atmospheric air from enterprises that are a source of foul-smelling emissions.

The object of the study is the sewage treatment facilities of a fish processing enterprise located in the Rostov region.

At the moment, an impressive number of scientific papers have been published that touch on such an urgent problem as the release of foul-smelling substances and associated gases by animal husbandry enterprises, farms, and closed-type complexes for raising livestock and poultry.

It is noted in the technical and scientific literature that the methodology for purification and reducing the volume of polluted air is based on methods for acidifying manure (or manure runoff) with waste sulfuric acid (H2SO4) to a pH level of 4.5-5.3 ± 2, as well as an alkaline solution of sodium hypochlorite (NaOCl) [3, 4]. Both reagents are widely used in agricultural practice and with the correct approach to use and disposal do not pose a threat to the environment. For dilute NaOCl solutions, bactericidal, fungicidal, antiprotozoal, immunomodulatory properties are peculiar, as well as the absence of toxic, mutagenic, and carcinogenic effects. Therefore, NaOCl is widely used as a veterinary drug for the...
treatment of various animal diseases. Sulfuric acid is used on pig farms in Sweden and Denmark to acidify manure to pH 5.5, to reduce the emission of ammonia (NH3) from manure runoff [4-9]. At the same time, in terms of ecologization and reducing the enterprise’s financial costs, the most rational method is the use of sorbents and absorbents of natural origin, such as silicon-containing species, wood chips, natural peat, etc. These materials quite effectively remove pollutants and harmful substances from water and air (depending on the used method), have a low cost, and are widespread almost throughout the entire territory of the Russian Federation [10].

2. Research

Based on information obtained from thematic literary sources, a new air purification system, the principle of which would be based on the absorption of foul-smelling gases, is considered; the absorption implemented at one of the local fish and seafood processing complexes. Air monitoring in the working area was carried out at the sewage treatment facilities (hereinafter referred to as STF) of the fish plant (Novoshakhtinsk, Rostov region). Table 1 shows data on the main technological units of the STF, meteorological conditions, the general physicochemical pollutants’ composition as well as their quantitative content at various stages of treatment.

Table 1. The gas emission parameters of fish plant STF machines and meteorological conditions.

| Parameter            | Traveling screen | Grease removal tank | Skimmer | Membrane bioreactor | MPC of the working area |
|----------------------|------------------|---------------------|---------|---------------------|------------------------|
| Humidity, %          | 45.2             | 38.0                | 37.9    | 37.3                |                        |
| T, 0C                | 29.5             | 28.7                | 28.8    | 36.6                |                        |
| V, m/sec             | 0.1              | 1.1                 | <0.05   | 0.2                 |                        |
| CO, (mg/m³)          | 3.4              | 1.2                 | 0.9     | 0                   | 20                     |
| NO2, (mg/m³)         | 0                | 0                   | 0       | 0                   | 2                      |
| NO, (mg/m³)          | 0                | 0                   | 0       | 0                   | 0                      |
| SO2, (mg/m³)         | 2.7              | 3.2                 | 4.2     | 19.7                | 10                     |
| H2S, (mg/m³)         | 0.087            | 0.111               | 0.490   | 4.813               | 10                     |
| HCHO, (mg/m³)        | 1.44             | 1.21                | 1.53    | 2.0                 | 0.5                    |

The technological scheme of the STF consists of several sequentially connected nodes:
- mechanical cleaning (traveling screens, sand traps, grease removal tanks);
- biological treatment (corridor aerated lagoons, membrane bioreactors with removal of nitrogen compounds and excess sludge);
- reagent treatment (pressure skimmers with coagulation, removal of phosphates, fats, activated sludge);
- disinfection (ultraviolet).

The studies were carried out in the summer (07/29/2020).

Measurements of the amounts of specific components of the gas-air mixture were carried out with a Geolan-1P gas analyzer (verification certificate No. 06.032600.20) (Fig. 1). During one measurement cycle, at least three samples were analyzed; the average result is shown in Table 1 [11-14].

Analysis of the data (Table 1) allows us to conclude that the MPC for the content of many types of pollutants significantly exceeds the permissible indicators of the norms established by sanitary and epidemiological requirements.
Figure 1. The process of studying the components of the gas mixture above the membrane reactor of the local treatment facility (LTF).

To reduce the concentration of SO2 in the air of the STF working area, an air purification system based on biochemical processes was proposed (Fig. 2).

Figure 2. General view of the biofilter model.

As a sorbent, a mixture of vermicompost (produced as a result of processing organogenic waste from animal husbandry, crop production, and sewage sludge by earthworms of the Lumbricidae family) and larch bark was used (Fig. 3).
3. Results

Analysis of the obtained results shows that in each time interval, there was a decrease in the concentration of SO2. SO2 MPC in the working area above the treatment facility (less than 10.0 mg/m³) was achieved 40 minutes after the start of gas purification in a biofilter [15-17].

In the biofilter model, a mixture of fractionated loading from larch bark of different fractions ("small bark" 10-20 mm and "large bark" 22-40 mm), vermicompost without moisture ("dry"), and with moisture ("wet") was used as an absorbent (Fig. 5) [18, 19].
Figure 5. Parameters of gas purification from sulfur dioxide in a biofilter.

Analyzing the results, we can see that there is a decrease in the content below the MPC of the working area when the biofilter is loading with a carrier with biomass from a 20, 40, 60 cm height larch bark with fractions of 40-80 mm and a 10 cm height supporting layer of larch bark with a fraction of 20-40 mm. At the same time, the residual gas concentrations on a humid load with a bark of 60 cm are less than on a dry one. As follows from the graph, the residual gas concentrations in the “small bark” fractions are lower than in the “large bark” regardless of the initial moisture content. It can be concluded that production plants of biofilters should be loaded with fractionated loading from the bark of 10–20 mm in size [20-26].

4. Conclusion

From the above experimental data, the advantages of the applied biologically active filter material include:
- achievement of standards for sulfur dioxide;
- no waste generation requiring special treatment;
- the possibility of widespread industrial implementation at facilities for the processing of animal raw materials and livestock complexes;
- the technology is based on low-cost, energy-saving principles.

Ease of use in the industrial operation of this sorption material allows maintenance of the biofilter without the involvement of specialized personnel.

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