Perspective of using the biological method for gaseous emissions cleaning in the food productions

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Abstract. The article considers the problem of contamination of exhaust gases of confectionery plant because of harmful substances and unpleasant odors. A confectionery production uses a wide range of aromatic substances. Moreover, despite the presence of operating air treatment facilities the specific smell of ambient air could be sensed. To identify the most powerful sources of odor emissions the organoleptic study was conducted. Also, with the help of olfactometric study of the sources of odor, the composition of the aromatic mixture with a predominant content of terpenes and benzaldehyde was revealed. Several methods of treatment of gases-air emissions were studied including biological, thermal and thermocatalytic. Among the biological ways of air treatment, three types have been considered: traditional biofilters, trickling biofilters and bio scrubbers. Bacteria that helps to decompose aromatic substances like benzaldehyde or some of the terpene series have been found. Additionally, the mechanism of transformation of odorous substances has been studied.

1. Introduction
The enterprises of the confectionery industry aren’t the main pollutants of the atmosphere, however, being within the city boundaries, they influence the quality of ambient air due to emissions of smelling substances [1]. The feature of the considered gas-air emissions is the presence of a specific smell of aromatic compounds used at the enterprise, despite the presence of treatment facilities. It is known that when several pollutants are in the ambient air that cause unpleasant sensations, the person’s sense of smell perceives the presence of only one gas, which has the strongest odor, as it masks the remaining gases. The presence of even minor concentrations of these substances in the air causes dizziness, headaches and even neuralgia. At high concentrations, they affect the kidneys, causing diseases such as nephritis, pyelonephritis [2].

In this work, we studied the possibility of using the biological method for the purification of gas-air emissions from a confectionery plant from volatile flavoring compounds (VFC).

To achieve this goal, the following tasks were considered: determining the concentration of odor, studying the composition of the gas-air mixture of a confectionery enterprise, considering the possibility of using the biological method to purify air from aromatic compounds.

2. Materials and methods
There are various methods to neutralize odors from the confectionery industry exhaust gases, namely: thermal and thermocatalytic, absorption and adsorption methods, gas-phase processing. Thermal and
thermocatalytic methods are based on the processes of destruction and oxidation of pollutants atmospheric oxygen at high temperatures using special catalysts [3]. During gas-phase processing, ozone is introduced into gas-air emissions or special substances that neutralize odors [4]. In the absorption method, gases are flushed with liquid absorbers, for example, aqueous solutions of alkalis, acids, oxidizing agents [5]. During adsorption, unpleasant smelling substances are absorbed by solid sorbents [6]. However, these methods require the presence of certain chemicals and catalysts. And besides, as a result of such purification, products appear that become sources of secondary pollution [7]. In this regard, biological treatment has great prospects.

The principle of biological treatment of exhaust gases is based on the fact that microorganisms act on the corresponding organic substances with their transformation into harmless compounds [8]. In this work, the possibility of using biological method for the additional treatment of gas-air emissions of the confectionery plant from volatile flavoring components (VFC) was considered.

At the first stage, it was necessary to identify the most powerful sources of odor emissions, which was determined using organoleptic examination of the sources.

To determine the level of negative effects of odor, an olfactometric study of the sources of odor was performed. Smell samples were taken in sampling bags. Bags for the vacuum sampler are made of polyethylene terephthalate (PET, nalofan). This material is suitable for odor sampling, since it practically does not adsorb organic substances. Connecting and sampling tubes are made of polytetrafluoroethylene.

Samples taken from the studied sources (from 1 to 14) were subjected to olfactometric analysis to determine the odor concentration and instrumental analysis using a gas analyzer to measure the concentration of volatile flavorings compounds (VFC).

3. Results of the study of perspective of the biological treatment of gas emissions from VFC

The experimental results of the study of perspective of the biological treatment of gas emissions from VFC are given in table 1.

The values of odor concentration and VFC are the averaged values for three samples, show the concentration of VFC used in the confectionery industry, taken from the design documentation.

| Number of sources | Source Name                        | Concentration of odour, UO / m³ | Concentration of the amount of VFC, rel. units | VFC |
|-------------------|-----------------------------------|-------------------------------|-----------------------------------------------|-----|
| 1                 | Glazing gild № 1                  | 1076                          | 13.3                                          | 1.0 |
| 2                 | Glazing gild №1                   | 1322                          | 8.4                                           | 0.97|
| 3                 | Internal warehouse of flavouring additives | 5114                          | 23.9                                          | 2.3 |
| 4                 | Glazing gild №1                   | 4894                          | 16.1                                          | 2.3 |
| 5                 | Glazing drum №5                   | 412                           | -                                             | 1.3 |
| 6                 | Glazing drum №8                   | 2021                          | 10.8                                          | 1.3 |
| 7                 | Mixing and rolling gild №1        | 7174                          | 100.3                                         | 0.88|
| 8                 | Glazing shop number 2             | 1502                          | 8.4                                           | 1.3 |
| 9                 | Candy production line             | 3143                          | 12.8                                          | 1.4 |
| 10                | Glazing gild №2                   | 2313                          | 5.1                                           | 1.3 |
| 11                | Dragee production                 | 1307                          | 2.7                                           | 2.2 |
| 12                | Cooling Cameras                   | 23716                         | 62.8                                          | 1.2 |
| 13                | Chewing gum settling rooms        | 5349                          | 19.7                                          | 0.6 |
| 14                | Chewing gum settling rooms (tempering) | 1087                          | 7.8                                           | 2.2 |
| 15                | Chewing gum production line       | 3161                          | 75.3                                          | 5.9 |
According to the results of pollutant dispersion calculations, three sources making the most contribution to air pollution at the border of the sanitary protection and residential zone have been identified (No. 11, No. 12, and No. 14). The total contribution of these sources is about 70% (about 40% for No. 11, about 20% for No. 12, and about 10% for No. 14). The contribution of other sources varies from 0.4% to 6.7%.

The next task was to determine the composition of the aromatic compositions has been analyzed. The results of chromatography-mass spectrometry analysis of flavors, conducted in accordance with the "Methodological recommendations on analysis unknown composition objects via gas-liquid chromatography, gas chromatography-mass spectrometry, high performance gas chromatography, mass spectrometry with inductively coupled plasma atomic emission spectrometry inductively coupled plasma methods by Mendeleev VNIIM" No. 01-07, show a significant content of terpenes (limonene, menthol) and benzaldehyde.

Considering the possibility of using a biological purification method, microorganisms capable of transforming the volatile components of flavours have been found, and the mechanism of transformation of these substances has been studied. The results are presented in table 2.

| Type of microorganism | The name of the flavoring component | The mechanism of biotransformation |
|-----------------------|-----------------------------------|----------------------------------|
| **Rhodococcus opacus** d- limonene | Biomass from the culture of the glucose-toluene chemostat converts d- limonene to trans-carveol, which is then oxidized to carveone trans-carveol by dehydrogenase [9] |
| **Pseudomonas putida** | Limonene | Converts limonene to p-ment-1-ene-6,8- diol and perillyl alcohol [10] |
| **Rhodococcus erythropolis DCL14** Limonene | Epoxide hydrolase from Rhodococcus erythropolis DCL14 catalyzes the hydrolysis of limonene-1,2-epoxide to limonene-1,2-diol [11,12] |
| **Thauera terpenica 21 Mol** Menthol | Thauera terpenica 21 Mol converts menthol as a source of sole carbon. The mechanism of degradation involves oxidation reactions leading to ment-2-enone, followed by hydration and an additional oxidation stage [13] |
| **Castellaniella defragrans** Limonene | As an initial stage, oxygen-independent hydroxylation of the methyl group of limonene to perillyl alcohol occurs, followed by oxidation to perillic acid. [14] |
| **Saccharomyces cerevisiae** Benzaldehyde | Biotransformation of benzaldehyde into free cells L-phenylacetylcarnbolbi - yeast effect from β-cyclodextrin [15] |

Three existing biotechnological solutions for biological gas treatment have been considered: traditional biofilters, trickling biofilter and bio scrubbers.

Biofilters are open bulk sites filled with natural charging material (peat, sawdust, compost, pieces of bark, etc.) [16]. The formation of the microbial community proceeds naturally on the filler particles. However, the load of natural origin is staked over time, which leads to deterioration of the efficiency of purification, and can also serve as a habitat for microorganisms that are antagonists of active biomass [17]. In addition, such a biofilter requires humidification of the incoming air for the most complete extraction of pollutants by bacteria, which is solved by the introduction of a gas scrubber- humidifier. Among the weakness of traditional biofilters, the authors [18] also note the lack of a constant supply of fluid to the body of the biofilter and conclude that such a biofilter is most effective for cleaning gases from hydrophobic and poorly water-soluble compounds. It also indicates a relatively small amount of pollutant extraction (compared to other methods).
The configuration of the trickling biofilter reactor is generally similar to the traditional one. One of the main differences is the continuous supply of the liquid droplet phase and the use of inert feed materials - fillers. In trickling biofilters, polluted air is passed through a column with a filler, in which the liquid circulates [19]. The contaminant is dissolved in the liquid film, and then captured by microorganisms growing on the surface of the filler. The fluid provides moisture, nutrients, pH control in the biofilm and allows to remove inhibitory products. Ideally, excess biomass is also removed by liquid droplets, thereby achieving equilibrium and stable operation of the biofilter. However, in practice, the circulating fluid does not cope with excessive growth of the microbial mass [20], which leads to an increase in hydraulic resistance, a reduction in the residence time and a drop in productivity. In extreme cases, the biofilter reactor is closed and cleaned. Some authors [17,18] suggest other options to control the growth of microbial populations while maintaining microbial activity. These ideas include selecting of the size and structure of the filler, limiting the supply of nutrients and adding inhibitors. The possibility of using microbial predators, such as protozoa and nematodes, is also indicated.

![Biofiltration Diagram](image)

**Figure 1.** Schematic representation of bio-scrubber

Bio-scrubbers for gas purification are characterized by the release of two processes: the absorption of volatile compounds into water and the biological purification of water in a bioreactor. Exhaust gas is served in an absorbent column with a layer of filler and a countercurrent of gas and water, in which pollutants are converted into a liquid form. Gas-liquid absorbent columns are designed to facilitate mass transfer from the air in the liquid phase, thereby reducing the amount of equipment [21] and maintaining the hydraulic resistance.

Water then enters the bioreactor - a tank with an aeration system containing activated sludge, which is involved in the process of neutralizing pollutants. The volume of the reactor is much larger than the volume of the absorbing column (Figure 1). To maintain microbial activity, nutrients should be added to the water bioreactor. Additionally, titrants can be added to control the pH of the aqueous phase.
Advantages of bio-scrubbers compared to biofilters are: less equipment, better pH control, more reliable and predictable results, no problems with clogging of packaging materials, lower occurrence of toxic concentrations in the liquid phase [21].

The last two points are, at the same time, advantages over trickling biofilters. Among the weaknesses, the need to remove waste sludge and prevent periods of downtime are noted.

4. Conclusion
As a result of the conducted research, sources of volatile aromatic compounds of confectionery production making the most contribution to air pollution by terpenes and benzaldehyde have been identified. Additionally, the strains of microorganisms that can transform the detected aromatic compounds in the process of biotechnological air purification have been selected. And constructive and technological features of biotechnological installations for cleaning the gas-air mixture are considered.

The obtained data allows to consider the method of biological transformation of residual volatile components of flavoring with the help of special strains of microorganisms as promising and reasonable in terms of efficiency, safety and economically feasible.

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