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Decomposition of individual components of bio-organic waste: volatile organic compounds and the impact on health and psycho-emotional state

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Abstract. The study considers the impact on the person's health and psycho-emotional state of unpleasant odors arising from the storage and accumulation of bioorganic waste, including food waste (meat, poultry, fruits and vegetables) and bird droppings. The survey data of poultry and livestock farms' employees in Serbia are given. The impact of unpleasant odors on the Waste sorting complex (Moscow region) employees' vital signs is assessed. The impact of high-intensity odor groups for individual components of food waste (pork meat, poultry meat, vegetables and fruits) and bird droppings was studied by interviewing volunteers and measuring their vital signs.

Keywords: bioorganic waste, odorants, volatile organic compounds, VOC, bio-organic waste components, odor groups, health effects

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Authors' contributions. All studies were organized and conducted under the guidance of Ph.D., Associate Professor *M.D. Kharlamova,* Direct measurements were carried out at private agricultural enterprises in Serbia and in the laboratories of Serbian Oil Industry Company (NIS). Graduate students *M. Adamovich, M.A. Spirin, K.S. Romanovskaya* and student *L.R. Mustaeva* took direct part in the surveys. Consulting services and partial processing of the results were performed by *N. Adamovich.*

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Разложение отдельных компонентов биоорганических отходов: летучие органические соединения и их влияние на здоровье и психоэмоциональное состояние

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Аннотация. Рассмотрено влияние на здоровье и психоэмоциональное состояние человека неприятных запахов, возникающих при хранении и накоплении биоорганических отходов, в том числе пищевых отходов (мяса, птицы, фруктов и овощей) и птичьего помета. Приведены данные опроса работников птицеводческих и животноводческих ферм Сербии. Оценено влияние неприятных запахов на показатели жизнедеятельности работников Комплекса по сортировке отходов (КПО) (Московская область). Влияние групп запахов высокой интенсивности на отдельные компоненты пищевых отходов (мяса свинины, мяса птицы, овощей и фруктов) и птичьего помета изучали путем опроса добровольцев и измерения их показателей жизнедеятельности.

Ключевые слова: биоорганические отходы, одоранты, летучие органические соединения, ЛОС, компоненты биоорганических отходов, группы запахов, воздействие на здоровье

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Introduction

Aerobic and anaerobic decomposition of bioorganic waste is accompanied by a consistent transformation of the organic mass, which is associated with the development of specific microbiocenoses. The activity of microorganisms leads to chemical transformations of biopolymer organic molecules – proteins, fats, carbohydrates, and the appearance of a wide range of volatile organic compounds (VOCs), including those that may have an unpleasant odor and are odorants[1]. It is reliably known that the process of anaerobic decomposition of bioorganic waste is already at the first stage accompanied by the formation of simple inorganic compounds, such as ammonia and hydrogen sulfide, which are also odorants; volatile organic compounds can be formed starting from the second – acidogenic stage of decomposition. It must be remembered that during storage and, especially, the accumulation of waste, both types of processes occur simultaneously – in the surface layer, up to 25-30 cm thick, aerobic oxidation processes can also occur, however, the products of fat hydrolysis (saturated and unsaturated organic acids, including volatile ones), proteins (amino acids and amides), as well as products of subsequent redox reactions have the most unpleasant odor. Thus, the resulting odorants can have a variety of qualitative and quantitative composition – from the simplest molecules of hydrogen sulfide, dimethyl and diethyl sulfides and methyl mercaptans, aldehydes and alcohols, to more complex aromatic compounds, terpenes and organic acids [1–3]. Many of the compounds formed are toxic, which can adversely affect the health of people working in livestock and poultry farms, MSW landfills, waste sorting plants and composting stations.

According to the authors [5; 6], the impact of unpleasant odors caused by volatile organic compounds is a real problem for the population living in settlements located in the areas affected by MSW landfills, waste sorting and agro-industrial complexes, as well as for workers of these enterprises.

The negative impact of some odorants on human health has been studied quite well. So, according to the data [7], the most dangerous components, found in emissions at all stages of MSW technological processing, are dichloroethane, trichlorethylene, as well as naphthalene and acrolein. An unpleasant odor can affect

[1] …Isparljiva organska jedinjenja. Available from: https://evocs.org/o-voc-u/ (accessed: 01.10.2022); Volatile Organic Compound. Available from: https://www.sciencedirect.com/topics/medicine-and-dentistry/volatile-organic-compound (accessed: 01.10.2022).

an increase in heart rate, heart rate variability, blood pressure, respiratory rate, skin conduction reactions, sleep, as well as emotional characteristics and cognitive abilities of the subjects [8]. Thus, the authors of [9] showed that the smell of ethyl mercaptan adversely affects the performance of complex tasks that require maximum attention, but practically does not affect the solution of simple arithmetic calculations. Since the smell affects the functional state of the cerebral cortex, it also affects the entire body. Some odors lead to sleep disturbance and headaches, cause coughing, shortness of breath, indigestion, irritation of the nose and eyes [9; 10].

Unpleasant odors are complex mixtures formed by many individual odors, but a person usually reacts only to the most strongly smelling components. The authors of [11] note that the main problems in determining the degree of odor impact on health, emotional state and cognitive functions of a person are associated with the lack of a unified methodology for conducting the experiment – differences in the methods of odorant delivery, exposure time, measured response. When conducting studies of the reaction of residents living near the object of the smell, the methods of questioning the population [6] are most often used, which, however, do not give a sufficiently reliable result, since they do not take into account many factors, for example, "...the influence of individual addictions and individual past experience on the caused odor effects" [8]. Usually, researchers conduct a survey of adult residents, taking into account the gender of the respondent, the distance to the odor source, assessing the frequency of odor perception and its intensity, in some studies a dispersion model is used, taking into account the amount of emissions and meteorological conditions [6]. To determine the reaction of the subjects to a particular odorant, experiments were carried out with a reference substance – N-propyl mercaptan, the exposure of which was carried out for six weeks, while a total of 15 symptoms were recorded, for example, headache, asthma attacks, eye irritation, runny nose and nausea. The authors of the article found a correlation between the number of days when a strong smell was perceived and the total number of reported symptoms [12].

In this study, the goal was to determine the complex effect of the decaying bioorganic waste smell, including components that have the most unpleasant odor, on the psycho-emotional state and vital signs of a person, taking into acount age, gender, work experience, duration of stay in the zone of odor exposure.

Research methods and results

In the article, the authors used three methods to determine the intensity and degree of bioorganic waste odors' impact on the general physical condition (by changing the main vital signs) and on the psycho-emotional state of the test volunteers: a questionnaire, an expert assessment method, and an experimental study of the volunteers' vital signs when exposed to the unpleasant smell of meat waste.

1. Questionnaire

The survey was conducted at various production facilities, including a waste sorting complex (WSC) in Moscow region; a large poultry farm (there are 234 thousand in the winter, and 215 thousand birds in the summer), and a private poultry farm (there are 34 thousand birds) in Serbia, Belgrade district. A total of 27 workers who had direct contact with food waste and bird droppings took part in the survey (see Figure 1a). When analyzing data on respondents, gender, age (all employees were divided into three categories), length of service (three categories) at a given enterprise, and duration of exposure to odors during the working day (two categories) were taken into account. The data are also presented in Figure 1b.

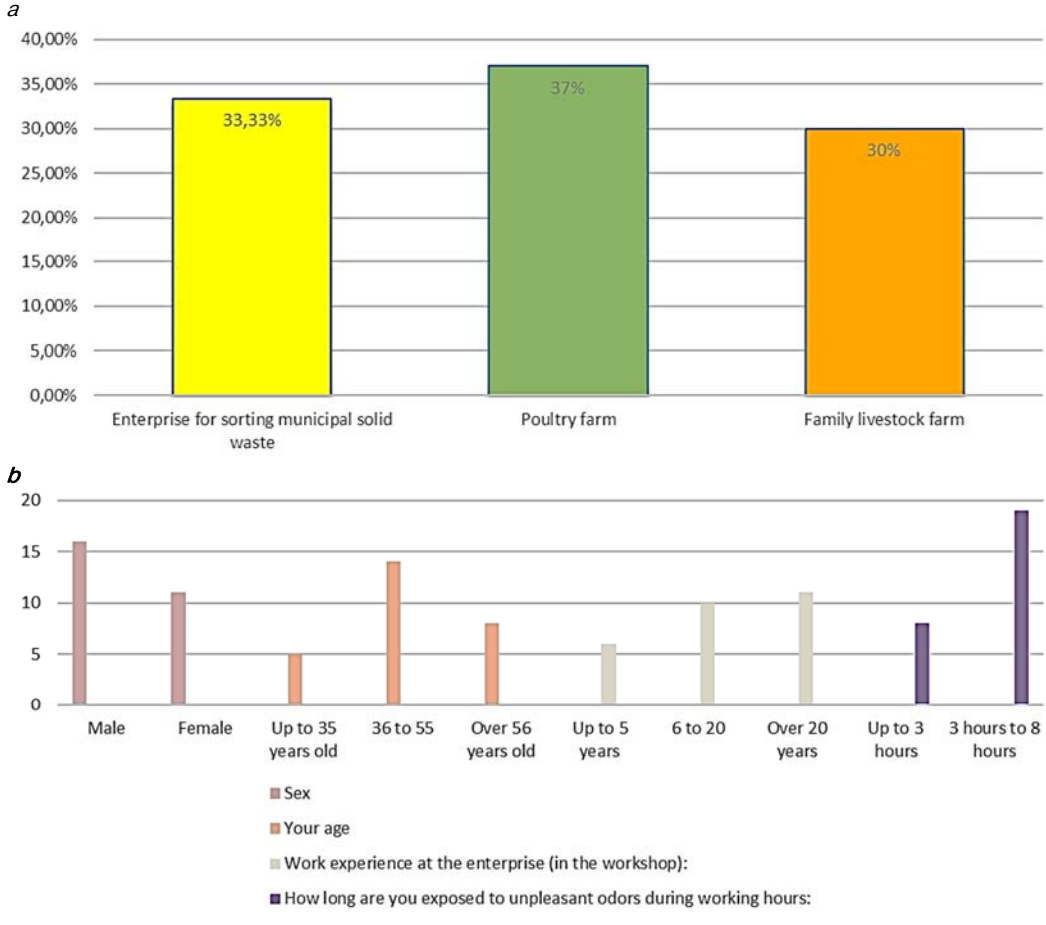

Figure 1. Distribution of surveyed respondents by production facilities (a) and data on respondents (b)

The survey involved 16 men (60%) and 11 women (40%), the majority of employees were people of mature age aged 35-65 years (74%). The majority of respondents (41%) have been working at the enterprise for more than 20 years (82% of men and 18% of women) and stay at the workplace for a long time – from 5 to 8 hours.

The questionnaire included two blocks of questions: about the consequences of the impact of smell on the well-being of respondents (assessment of physical condition and health indicators) and their performance (assessment of productivity and attention). The list of questions in the questionnaire is presented in Table 1.

Table 1. List of questions in the questionnaire

Question	Answer options
1. How bad odors affect your productivity:	1. Does not affect 2. Partially reduces 3. Completely reduces
2. How bad odors affect your concentration?	1. Does not affect 2. Partially responsive to attention (difficulty concentrating) 3. Completely reduce attention (impossible to concentrate) 4. Other (specify)
3. Do you have any chronic or respiratory diseases at the time of the survey? (if yes, choose disease)	1. No 2. Allergic bronchitis 3. Allergic rhinitis 4. ORVI 5. Asthma 6. Other (specify)
4. How often (during the year) did you visit the doctor in connection with an exacerbation of a chronic disease?	1. Never 2. Once 3. Twice 4. Repeatedly
5. What sensations do bad odors make you feel?	1. No sensations 2. Nausea 3. Dizziness 4. Sore throat 5. Cough 6. Headache 7. Abdominal pain 8. Burning eyes and tearing 9. Increased heart rate 10. Clouding of consciousness 11. Other (specify)
6. During the past year, how often have you consulted a doctor due to the consequences of exposure to unpleasant odors:	1. Never 2. Once 3. Twice 4. Repeatedly
7. How often have you been absent from work (used sick leave) in the last year due to the consequences of exposure to unpleasant odors:	1. Never 2. Once 3. Twice 4. Repeatedly
8. Do you consider it necessary to take measures to reduce odor in the workplace?	1. Necessarily 2. Possibly 3. No need

On Figure 2 the results of these enterprise employees' survey is presented.

All subjects were expressly asked about the advisability of carrying out special measures to reduce the intensity of the smell.

From the answers to the first set of questions, it can be seen that working capacity is partially or completely reduced in 66% of respondents: 44% of men of mature age believe that working capacity is reduced partially, 36% of young women (under the age of 35) believe that working capacity is reduced completely, while the smell does not affect the working capacity of women of mature age (64%).

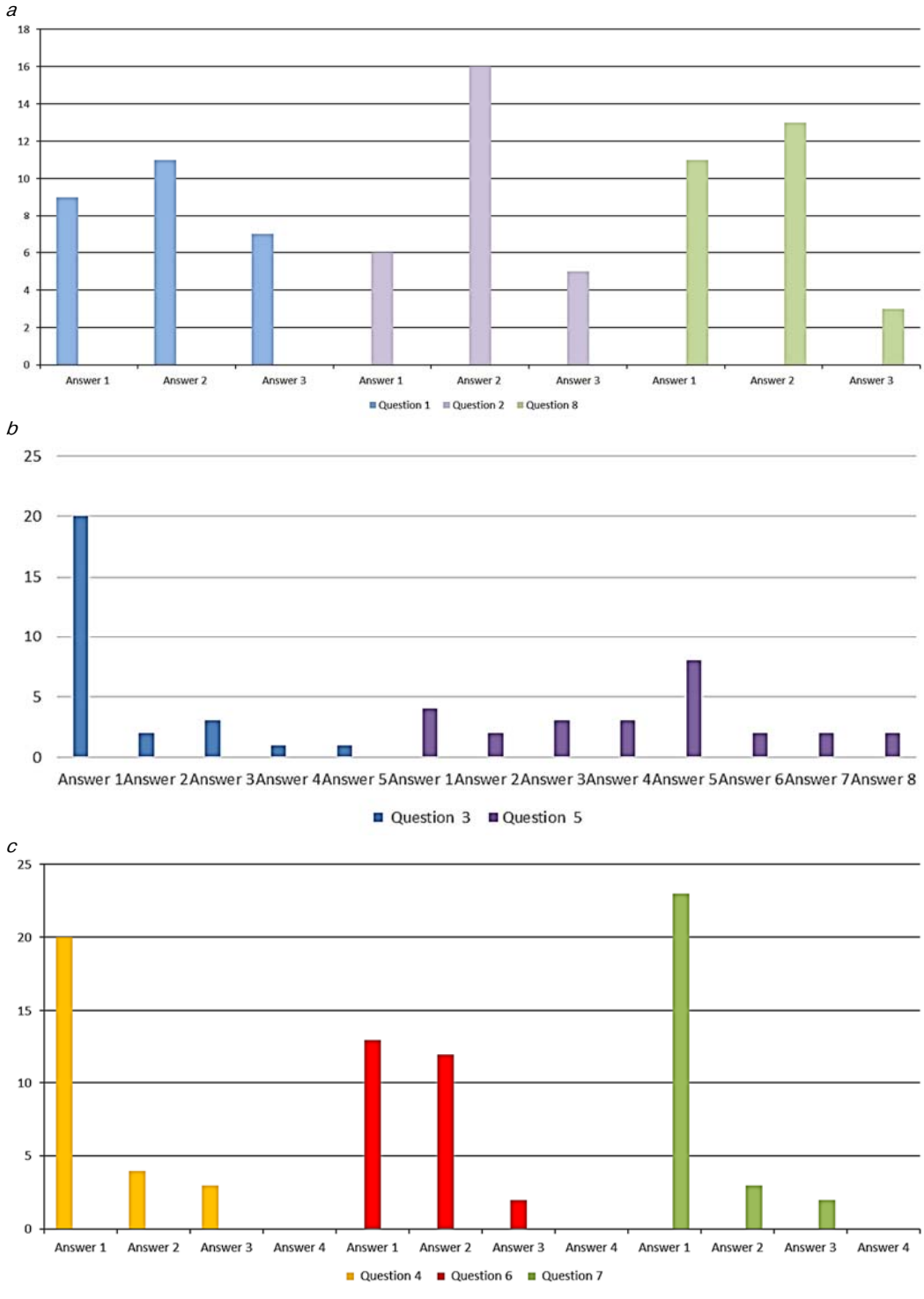

Figure 2. Results of a survey of employees of manufacturing enterprises

Odors reduce attention concentration in 77% of respondents: 50% of men believe that attention concentration is reduced partially, 27% of young women believe that attention is completely reduced, and only one woman (under 35 years of age) notes a partial decrease in attention concentration.

The study found that 75% of respondents at the time of the study did not have chronic respiratory diseases (allergic bronchitis, allergic rhinitis, asthma), and 25% of respondents suffered from allergic rhinitis. At the time of the study, none of the respondents had acute symptoms of acute respiratory viral infections (fever, cough).

According to the results of the survey, it was found that 85% of all respondents noted the appearance of some somatic symptoms: cough, nausea, dizziness, burning eyes and lacrimation, sore throat, headache. The main symptom in 30% of the total number of respondents was a cough, the rest of the discomfort accounts for about 10%.

Cough appeared in 31% of men and 37% of women suffering from allergic diseases. Sore throat was experienced by 12.4% of respondents, of which 67% of men and 33% of women who do not have chronic diseases.

Dizziness was experienced by 9.92% of them, 33% of men and 67% of women who did not suffer from diseases, headache appeared in 7.44% of respondents, of which 50% of men and 50% of women did not have chronic diseases.

Abdominal pain and nausea began to be experienced by 8.26% of female respondents; men did not experience these symptoms. All women did not suffer from chronic diseases.

Burning in the eyes and watery eyes were experienced by 7.44% of the respondents, of which 30% were men and 70% were women. Of these, 80% of men suffered from allergic rhinitis, and 20% did not have chronic diseases of the upper respiratory tract. At the same time, 75% of women experiencing lacrimation had chronic diseases, and 25% did not.

None of the respondents went to the doctor after the onset of unpleasant symptoms, the discomfort from the unpleasant odor was not critical for them and did not require medical attention. But 24 out of 27 people (89%) consider odor reduction measures to be mandatory or possible.

2. Peer review method

The odor intensity was assessed by expert volunteers on a 5-point odor intensity scale – by analogy and in accordance with the method for determining the odor intensity of water (GOST 3351-74): 0 points – no smell; 1 point – the smell is very weak, indefinite; 2 points – the smell is weak, but definite; 3 points – the smell is moderate; 4 points – the smell is strong; 5 points – the smell is very strong. The degree of odorization was considered sufficient when at least three testers gave an intensity rating of at least three points. The experiment was carried out in the laboratory of the Serbian Oil Industry Company (NIS), Lubricants Production and Logistics Plant (Republic of Serbia). The results of the study are presented in Figure 3.

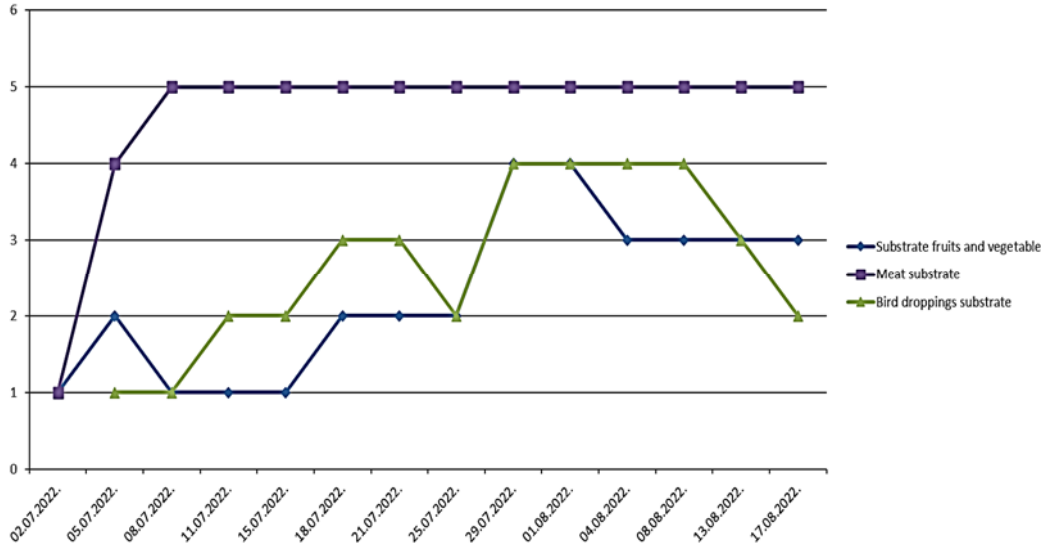

Figure 3. Results of determining the odor intensity of food waste fractions and bird droppings

For seven weeks, every three days, experts (3 people) measured the odor intensity of the meat substrate, the fruit and vegetable substrate, and the bird droppings substrate. According to experts, the meat substrate has the most unpleasant and persistent odor, as shown in the graph. Experts noted the appearance of negative symptoms – dizziness and nausea. The substrate from fruits and vegetables, according to experts, has a pronounced moderately sweet, but unpleasant odor that caused coughing from the 20th day of the experiment. The smell of bird droppings substrate caused burning in the eyes and watery eyes of the experts, starting from the 6th day, which is associated with the release of large concentrations of ammonia. On the 33rd day of the experiment, a pronounced decrease in the intensity of the odor of the bird droppings substrate was found.

Thus, the results of the study show that the smell of food waste fractions and bird droppings causes some psychosomatic symptoms and negatively affects the functional state of the human body.

3. Study of vital signs

The purpose of this experimental study was to determine the impact on the main vital signs of a person (temperature **T**, heart rate **HR**, blood pressure **BP**, saturation level **SL**) of odorants formed during the decomposition of MSW components. The studies (measurements of vital signs) were carried out in two stages with the involvement of volunteers.

At the first stage, vital indicators were measured in workers at the MSW sorting enterprise, where 9 people took part in the experiment. In this study, the complex impact of MSW was determined, without division into fractions.

At the second stage, the study of indicators was carried out in a laboratory, where 20 people participated in the experiment, while determining the impact on vital signs of the smell of decomposition of meat components of MSW.

The work was carried out in accordance with the Declaration of Helsinki on the ethical principles of medical research [17] and in compliance with the principle of confidentiality of the information received, ensuring the right of a person to refuse to participate in the work, informing about the use of the information received. Before starting work, each volunteer signed an informed consent to participate in the work. All volunteers received an explanation regarding the work schedule.

The temperature of the subjects was measured remotely using a non-contact infrared thermometer, pulse and blood oxygen concentration were measured using the Armed YX200 portable pulse oximeter, and blood pressure was measured using an Omron M2 Basic tonometer.

At the enterprise of MSW sorting, the authors measured the vital signs of workers before and after the shift (Table 2). A total of 9 people were examined – 5 women aged 22 to 61 years, and 4 men aged 38 to 46 years. One of the women had abnormal blood pressure before the start of the experiment (150/100). Changes in the main vital signs (temperature, pulse, blood pressure) are presented in Table 2.

Table 2. **Vital indicators of employees**

№	Sex	Age	T		HR		BP	
			Before work	After work	Before work	After work	Before work	After work
1	W	28	36.9	36.8	68	65	120/80	100/70
2	W	22	36.7	36.8	70	68	120/80	100/60
3	W	48	36.4	36.5	71	70	120/80	120/80
4	W	50	36.7	36.9	78	79	150/100	170/110
5	W	61	35.0	34.5	74	72	130/80	120/80
Average value			36.34	36.30	72.2	70.8	122.5/80	110.0/72.5
6	M	38	36.5	36.2	73	74	100/60	100/80
7	M	46	36.5	36.2	74	76	140/90	120/80
8	M	40	36.5	36.5	75	74	120/80	100/60
9	M	44	36.2	36.4	76	78	150/90	140/80
Average value			36.32	36.42	74.5	75.5	127.5/80	115.0/75

Before the start of the shift, the temperature indicators of all employees, regardless of age and gender, corresponded to the norm. After the end of the work shift (8 hours of work), the temperature in women decreased by an average of 0.04 ºC, which is below the measurement error limits. In men, the temperature increased by 0.1 ºC, which is also within the measurement error of the thermometer.

It should be noted that the thermoregulation of the human body depends, first of all, on the establishment of a balance between heat production and heat loss and is associated with the functioning of thermosensitive nerve cells of the hypothalamus. Therefore, the temperature of the subjects, as a vital indicator, cannot be used as a reliable criterion for assessing the impact of odor on the state of the human body, which was proved by the studies.

The development of a state of non-adaptive stress may be associated with the negative effect of odor, which, in turn, can cause changes in vital signs, and, with prolonged exposure, cause various diseases [18; 19]. Toxic effects on the body can be one of the reasons for the change in the normal functioning of the heart and heart rate (HR), moreover, cause both bradycardia and tachycardia. In any case, it is necessary to fix the initial deviations from the state of the norm for a particular person.

Before the start of the work shift, all subjects had heart rate values within the age norm. After a work shift, 80% of women experienced a decrease in heart rate by 2–3 beats / min, which averages 1.4 beats / min. Unlike women, in 75% of men, the pulse increased by 1–2 beats / min, which averages 1.0 beats / min. However, such low deviations in a small number of subjects require further testing.

Some scientific studies note that the frequency and intensity of unpleasant odors are strongly associated with the growth of diseases of the endocrine system[2], which in turn can lead to changes in blood pressure.

As can be seen from Table 2, blood pressure (BP) studies revealed small changes in BP in both women and men with long-term (8-hour) exposure to an unpleasant odor. The numerical values of blood pressure in all subjects are significantly reduced: in women, systolic blood pressure $\Delta av. = -12.5$ units, diastolic blood pressure $\Delta av. = -7.5$ units; in men – systolic blood pressure $\Delta av. = -12$ units, diastolic blood pressure $\Delta av. = -5$ units. The exception is the blood pressure indicators in one woman with signs of arterial hypertension and an initial deviation of blood pressure from the norm (150/100), in which the indicator increased even more after the work shift (170/110). These data were excluded from the calculation of averages.

In a few experimental studies of the effect of odor on the state of the human body, volunteers, as a rule, are exposed to a single odorant with an unpleasant odor (the smell of hydrogen sulfide, mercaptan, pyridine, butyric or valeric acids, etc.), but under real conditions, odors are are complex multicomponent mixtures [10].

In this laboratory study, the goal was to study the impact on the main vital signs (temperature T, heart rate HR, blood pressure BP, saturation level SL) of volatile products that have the most unpleasant odor, namely, the smell of decomposition of the meat substrate, on the 18th day (second stage decomposition) when the smell is most intense (see Figure 3).

In this case, volatile products (odorants) are decomposition products of amino acids and fats. It is this group of odorants that contains the most unpleasant-smelling products of decarboxylation, oxidative, reductive and hydrolytic deamination – volatile amines or diamines, as well as other foul-smelling VOCs – indole, skatol (tryptophan decomposition products), phenol, cresol (tyrosine decomposition

[2] WMA Declaration of Helsinki with amendments and additions made from 1964 to 2008 "Ethical problems of the principles of conducting medical research with part of people as subjects." Adopted at the 18th General Assembly of the World Medical Association. Helsinki; 1964. https://www.psychepravo.ru/law/int/helsinkskaya-deklaraciya.htm (accessed: 07.12.2022).

products), mercaptans (decomposition products of cysteine and methionine) [16]. The degradation products of lipids are various fatty acids, which also have an unpleasant odor.

In experimental studies of odors, olfactometers are usually used, which provide a very short exposure during one breath – during 5-10 seconds [10]. In this experiment, examinations of 20 volunteers aged 19 to 23 years (16 women, 4 men) were performed, who were in the zone of odor exposure (at a distance of 1.5 m from the source in a closed room) for 1 minute.

As can be seen from Table. 3, studies of blood pressure (BP) did not reveal significant deviations during short-term exposure to an unpleasant odor: in women – systolic blood pressure $\Delta av.$ = +0.6 units; diastolic blood pressure $\Delta av.$ = –1.4 units; in men – systolic blood pressure $\Delta av.$ = +4.3 units; diastolic blood pressure $\Delta av.$ =+0.3 units. This is consistent with the results of other researchers, for example [15].

When examining volunteers, the heart rate (HR) indicator changed most significantly in women – it increased by an average of 4 beats/min, in men this indicator remained practically unchanged, $\Delta av.$ = –0.5 beats/min (see Table 3).

The most indicative are the results of measuring the level of saturation in the subjects, since it is this indicator that is associated, first of all, with the direct participation of the respiratory organs. As can be seen from Table. 3, saturation in men and women significantly decreases: in women $\Delta av.$ = –2.1 units, in men $\Delta av.$ = –1.5 units, although none of the subjects revealed indicators exceed the norm for a healthy person (95–100%).

Table 3. **Vital signs of volunteers**

№	Sex	Age	T		HR		BP		SL	
			before	after	before	after	before	after	before	after
1	W	22	36.7	36.5	62	78	97/58	96/60	100	97
2	W	22	36.6	36.6	91	70	89/54	92/50	100	98
3	W	20	36	36	66	82	116/72	115/65	99	97
4	W	20	36.1	36.1	80	95	108/80	104/64	100	99
5	W	20	36.4	36.7	89	84	81/63	90/55	99	97
6	W	22	35.8	35.7	84	92	95/67	119/89	100	98
7	W	20	35.9	35.8	95	104	112/70	103/74	99	97
8	W	20	36.7	36.7	59	64	109/63	106/64	100	99
9	W	20	36.7	36.5	84	95	108/62	112/70	100	97
10	W	21	35.8	35.8	80	78	91/63	76/46	99	96
11	W	21	35.7	35.8	87	80	118/82	105/88	99	98
12	W	19	35.5	36	81	80	104/62	105/67	100	97
13	W	20	35.9	36	73	76	92/55	86/60	99	97
14	W	20	35.5	35.8	72	81	111/65	110/71	100	98
15	W	18	35.7	35.7	93	100	100/56	100/64	98	97
16	W	18	36	35.7	72	74	92/60	94/67	100	97
Average volue, women			36.06	36.09	79.3	83.3	101.4/64.5	100.8/65.9	99.5	97.4
17	м	23	36.4	36.2	70	72	109/64	115/68	98	96
18	м	21	35.5	36.1	67	58	107/64	96/58	100	99
19	м	20	35.9	35.8	80	84	112/52	114/56	99	98
20	м	23	35.7	35.7	113	114	133/76	119/75	99	97
Average volue, men			35.88	35.95	82.5	82.00	115.3/64	111.0/64.3	99.0	97.5

Conclusion

Volatile organic compounds (VOCs) can have a variety of structures and have complex effects on humans. Some VOCs that are odorants can be toxic and have high MPC values. Hence, it becomes necessary to control the process of VOCs release into the environment.

During the study, it was shown that an unpleasant odor interferes with the majority of respondents working at agribusiness enterprises or at enterprises in the field of waste management during work – it reduces efficiency, concentration and productivity. Almost 90% of respondents believe that it is necessary to eliminate unpleasant odors in the workplace, but do not consider it necessary to consult a doctor, that is, they do not attach much importance to the negative effects of odor, although an unpleasant odor leads to the manifestation of somatic disorders in them – coughing, dizziness, nausea, while respondents suffering from allergic diseases show symptoms more often (in 100% of cases).

As a result of the research, it was found that odorants formed during the decomposition of bioorganic waste components have a complex negative effect on some human vital signs. With prolonged exposure (8 hours), blood pressure changes most significantly in both men and women, while systolic blood pressure significantly decreases by an average of 12 units, diastolic – by 6.5 units. It should be noted that with prolonged exposure, the heart rate (HR) changes not so clearly and not so significantly – in 80% of women, a decrease in heart rate by an average of 1.4 beats / min is observed; unlike women, in 75% of men, the pulse increases by an average of 1.0 beats / min.

The study showed that body temperature cannot be used as a criterion for controlling the state of the body under the influence of unpleasant odors, since it primarily depends on the establishment of a balance between heat production and heat loss and is associated with the functioning of thermosensitive nerve cells and weakly depends on other external factors.

The study also found that even with a short-term exposure (within 1 minute) to the most unpleasant odor formed during the decomposition of the protein components of the waste (meat and poultry waste), heart rate and saturation levels change significantly. Significantly decrease in indicators of the level of saturation in both men and women: on average, in women – by 2.1 units, in men – by 1.5 units. Heart rate indicators significantly increase in women by an average of 4 bpm, in men, the heart rate does not change significantly.

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