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INFLUENCE OF CONDITIONS OF WATER PRODUCTION FROM AIR ON THE MICROBIOCENOSIS OF CONDENSATE

Представлені результати теоретичних і експериментальних досліджень впливу різних факторів на мікробіоценоз води із повітря. Встановлені закономірності між забрудненістю атмосферного повітря різними домішками, а також особливостями експлуатації настінних кондиціонерів спліт-систем та низкою показників мікробіологічного забруднення води. Показано, що вода, отримана із повітря за допомогою побутових кондиціонерів, характеризується значним мікробіологічним забрудненням і без спеціального очищення використовувати її для питних потреб небезпечно.

Ключові слова: *атмосферне повітря, побутовий кондиціонер, якість води, мікробіоценоз води із повітря.*

1. Introduction

Water production from the air is one of the ways of alternative supply of drinking or technical water to regions with a deficit of fresh water. In particular, it is possible to use such water in recreational areas of the south and east of Ukraine that do not have centralized water supply, and the quality of water from natural underground or surface sources is of low quality and requires a complex and expensive water treatment technology [1]. Also, it is possible to receive and use water from the air in the ATO zone [2].

To produce water from atmospheric air, various devices are used today, among which are also air conditioners. In modern sanatorium-resort complexes a significant number of domestic air conditioners are located. In the summer they are used to cool indoor air. The water, which is formed in them, is a secondary product, which, as a rule, is not used anywhere. Although the amount of it is enough to use after additional treatment and conditioning for certain needs of recreation center or sanatorium [1]. Therefore, the development of water treatment technology is topical, and the primary task of this work is studying the influence of the conditions for water production from air on its quality. The established regularities allow to determine the conditions under which water from air will have the best organoleptic, chemical and microbiological indices, and the technology of its further processing will require less resource costs.

2. The object of research and its technological audit

The object of research is the microbiocenosis of water, produced from atmospheric air with the help of domestic conditioners of split systems. The necessity of studying the microbiocenosis of water is primarily due to the fact that the specific features of its species and quantity make it possible to determine the epidemiological safety of such water and the possibility of its use in drinking or technical water supply. After all, the use of water, the quality of which does not meet the current hygiene standards, can lead to infectious diseases and parasitic infestations in humans.

One of the most problematic places of study of this object is that the microbiocenosis of the aquatic environment is characterized by a considerable variety of microorganisms. Therefore, within the framework of this work, only microbiological indices regulated by DSanPiN «Hygienic requirements for drinking water intended for human consumption» are determined [3]. In particular, the indicators of epidemic safety (total microbial number, bacteria of *E. coli*, *Pseudomonas aeruginosa*, *Staphylococcus aureus*), as well as a group of micromycetes, are determined. Information on these indicators is sufficient to justify the choice of effective technological regimes for the process of water disinfection and disinfection of containers and equipment that contact with water.

3. The aim and objectives of research

The aim of research is investigation of the influence of the conditions for water production from the air on its quality indicators, in particular microbiological ones.

To achieve this aim, it is necessary to solve the following tasks:

1. Determine the atmospheric conditions and the content of pollutants in the air in experimental air-conditioners.
2. Determine the effect of placing sampling points of air samples relative to sea level and remoteness from industrial enterprises, transport highways and the coastal strip to the level of air pollution.
3. Define the indicators of epidemical safety and other microbiological indicators of water produced from the air with the help of various wall conditioners of split systems operating in the «cooling» mode of indoor air.
4. Establish a relationship between air pollution, climatic conditions, design features and operating conditions of domestic air conditioners in split systems and microbiological quality indicators produced from air.

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5. Determine the conditions under which the condensate of atmospheric moisture from wall conditioners of split systems is expedient for use for drinking or technical needs.

4. Research of existing solutions of the system

To produce water from the air today use autonomous type wind generators, which produce electrical energy and water [4]. Also known about big-boards with a combined surface of hydrophilic and hydrophobic materials [5], «aquiferous trees» [6] or mesh panels with water-absorbing materials. In the offices for water production from the air, air dryers are used [7]. For regions with water and energy deficiency, it is proposed to use absorbing water ammonia refrigeration machines, solar radiation is used as an energy source [8]. Also, a domestic air conditioner can be used to produce water from the air [9–11].

A review of the literature on the problem of water production from air using air conditioners shows that very little research has been devoted to the quality of such water and the influence of various factors on it. Therefore, probably, in the discussions of this topic are presented completely opposite opinions. Some authors believe that the condensate from the conditioner can't be used for a person, and for technical needs it is suitable [12]. Others, on the contrary, say that such water is fairly clean [2]. There are also more thorough reflections on this issue. The authors note that the quality of the condensate from the air conditioner depends on the dust content of the air, the materials of the air conditioner, the correct installation of drainage pipes and the like. In this connection, the pollutants obtained from the air can contain various pollutants and their concentration will also be different. And after special treatment, water condensate from the conditioner can be used both in drinking (people, animals) and in technical water supply (irrigation of the land, watering of greenery, sanitation of premises and territories, work of fountains and cooling towers, etc.) [13–15].

Quite a different situation with the development of technical issues of water production from the air. In the literature [2, 4–11], various designs, calculation techniques and approaches to designing equipment or devices with which to condense atmospheric moisture are presented. It should be noted that the authors of the work have previously carried out experimental studies of the quality of water produced from the air with the employer of a domestic air conditioner [1]. But the study of the change in water quality, depending on the conditions in which it is obtained, was not conducted. And as noted above, such studies are important.

5. Methods of research

In the experiment, samples of water from the air are obtained during the operation of three household wall air conditioners. It should be noted that all air conditioners have been in operation for a long time at the time of the experiment. They cooled the air in the recreation centers on the territory of recreational areas and restaurant facilities along the Black Sea coast in Odessa and the Odessa region, Ukraine.

Places for obtaining samples of water from the air were selected so that they are used to produce air conditioners of the same manufacturer with the same technical characteristics (type of air conditioner, cooling capacity, voltage, type of refrigerant, circulating air flow). The air conditioners differed in design characteristics, namely the type of compressors and the system of filters for air purification (Table 1) [16, 17].

Table 1

Technical and design characteristics of experimental air conditioners

Main characteristics	Model of air conditioner and its number in the experiment	
	Sensei FTB-25GR (conditioner No. 1)	Sensei FTI-25MR (conditioners No. 2 and No. 3)
Type of air conditioner	split system	split system
Compressor type	not inverter	inverter
Cooling capacity, kW	2.5	2.5
Power consumption in cooling mode, W	0.82	0.65
Nominal voltage in cooling mode, V	220	220
Minimum air temperature in cooling mode, °C	+18	+18
Refrigerant	Freon R410A	Freon R410A
Drying mode, l/h	1	1
Circulating air consumption, m^3/h	500	500
Evaporator material	Copper tubes with hydrophilic aluminum finning exhibiting anticorrosive properties	
Air conditioner filters	mechanical+plasma	mechanical+antioxidant
Other functions	ionizer, autorestart	ionizer, autorestart

The height of placement of air conditioners above sea level and remoteness of air conditioners from pollution sources (industrial enterprises, transport mains) and the coastal strip is also different (Table 2). The distance between air conditioners and sources of air pollution is roughly determined by a geographical map in a straight line drawn from one point to another.

Table 2

Location of air conditioners in the experiment

Characteristic	Conditioner		
	No. 1	No. 2	No. 3
Geographical location of the air conditioner	Odessa region, Kominternovsky district, Chernomorske, recreation center «Chabanka»	Odessa, 13 station of Bolshoy Fontan, «Riviera» beach area	Odessa, Langeron beach
Height of the conditioner above sea level, m	2.8	3.0	2.5
Remoteness from: – coastal strip, m	250.0	100.0	150
– from the center of Odessa, km	32	15	3
– Odessa railway station, km	23	9.1	2.5
– Odessa sea port, km	27	12	2.6
– JSC Odessa Port Plant, km	24	58	47
– Sea trading port «Yuzhny», km	27	61	50
– JSC «Odessa Refinery», km	18	20	9.3
– Odessa International Airport, km	27	11	11

Samples of water from 3 air conditioners for this study were obtained during the day (30/05/2016). To determine the quality indicators, water samples taken around midday and midnight were used. In the obtained water samples, the epidemiological safety indicators were determined (Table 3). The obtained values of water quality indicators from air were compared with the requirements of [3]. Also, the values of similar quality indicators of water samples obtained from air under different conditions were compared.

Table 3

Methods and basic equipment used to determine indicators of epidemic safety of water

<table>
<tr><th>No.</th><th>Water quality index, unit of measure</th><th>Method of research</th><th>Laboratory equipment, devices, materials</th></tr>
<tr><td>1</td><td>Total microbial number, CFU in cm^3:
– at 22 °C;
– at 37 °C</td><td>The method of deep sowing a sample of water in nutrient agar and counting all colonies of microorganisms that can be seen at (2–5) fold increase, grown at a temperature (36±1) °C during (24±2) hours or at (22±1) °C for 48 hours in the depth and on the surface of the nutrient agar [18, 19]</td><td rowspan="7">– electric thermostats with automatic thermostat for temperature conditions (37±1) °C and (44±1) °C ;
– water baths for temperature regimes (75±5) °C, (45...49) °C (for nutrient media) (100±5) °C;
– cabinet drying, ensuring a constant temperature;
– a device for membrane filtration under vacuum with a filter surface diameter of 47 mm;
– device for creating a vacuum (0.5...1.0) atm;
– membrane filters with a pore diameter of 0.47 μm (Vladipor) or nitrocellulose membranes with a pore diameter of 0.5 μm;
– laboratory centrifuge;
– laboratory balance of general purpose of 4 classes of accuracy, with a weighing limit up to 1000 g in accordance with GOST 24104-80;
– laboratory analytical balances of general purpose and exemplary in accordance with GOST 24104-88 with the maximum weighing limit of 200 g, not lower than the 2nd accuracy class;
– a mercury thermometer with a measuring range from 20 to 200 °C with a scale division of 1 °C;
– a mercury thermometer with a measurement range from 0 to 100 °C with a scale division of 0.5 °C;
– pH-meter, providing a measurement with an error of ±0.01 pH;
– electric distiller, which ensures the quality of distilled water in accordance with GOST 6709-72;
– sterilizer with dry air for a temperature regime (180±5) °C;
– steam medical sterilizer according to GOST 19569;
– autoclave for sterilization at temperature (119...124) °C;
– household electric refrigerator;
– a fume hood for working with chloroform during the analysis of coliphages;
– electric tiles according to GOST 14919;
– light microscope according to GOST 8074;
– loop with double magnification;
– the optical turbidity standard is 10 units;
– dispensers for flooding nutrient media;
– pipetting dispensers according to TU 64-16-55-90 with a range of dose volume (20...200) cm^3, (200...1000) cm^3 and discreteness of setting the doses of 5 cm^3;
– bactericidal lamp;
– spirit-lamp according to GOST 25336;
– bacteriological loops;
– bacteriological floats;
– sterile cover slips according to GOST 6672;
– glass according to GOST 9284;
– Petri dishes according to GOST 25336;
– tripods for test tubes in accordance with GOST 12026;
– porcelain mortars with pestles;
– scalpel, GOST 21240;
– spatula, GOST 10778;
– anatomical tweezers for working with membrane filters;
– sandy clocks according to GOST 10576;
– tableware dimensional laboratory according to GOST 1770-74;
– laboratory utensils in accordance with GOST 25336-82
– flasks according to GOST 1770-74;
– pipettes, GOST 29227;
– test tubes GP-16-150 according to GOST 25336;
– glasses, measuring cylinders in accordance with GOST 177;
– funnels according to GOST 25336;
– containers for preparation of nutrient media;
– pencils or markers on glass;
– wool, medical hygroscopic cotton;
– filter paper;
– medical gauze</td></tr>
<tr><td>2</td><td>General coliforms, CFU per 100 cm^3</td><td>The method consists in filtration of a certain volume of water through membrane filters, cultivation of crops on a differential diagnostic nutrient medium with lactose and subsequent identification of colonies for cultural and biochemical properties. It is taken into account that the total coliform bacteria are gram negative, have no spores, oxidase-negative rods that ferment glucose and lactose to acid, aldehyde and gas at (37±1) °C for (24...48) hours. Among the common coliform bacteria are thermotolerant coliform bacteria that possess all of their characteristics and, in addition, are able to ferment lactose to acid, aldehyde and gas at a temperature of (44±0.5) °C for 24 hours [18, 20]</td></tr>
<tr><td>3</td><td>Escherichia coli, CFU per 100 cm^3</td><td>The method of determination consists in concentrating the bacteria from a certain volume of water using a membrane filter, incubating them at (37±0.5) °C on Kessler's and Endo's medium, differentiating the grown colonies and counting the number of bacteria of the Escherichia coli group per 1 dm of water. In the case of detection of gas in the culture medium or dark red colonies with metallic luster, then 2–3 such colonies from each sector are sown in parallel to tubes with a lactose medium and Hottinger broth to confirm the presence of E. coli. The lactose medium is preheated on a water bath to a temperature of (43...44) °C [18]</td></tr>
<tr><td>4</td><td>Enterococci, CFU per 100 cm^3</td><td>The method for the determination of enterococci (E. faecalis, E. faecium, E. avium, E. gallinarum) involves inoculation of a certain amount of the product when it is diluted in a liquid elective medium or on the surface of a dense elective medium, aerobic cultivation of crops at (37±1) °C during (24...48) hours, differentiation of the grown up colonies and its counting of microorganisms [21]</td></tr>
<tr><td>5</td><td>Pseudomonas aeruginosa, CFU per 100 cm^3</td><td>The determination is carried out by a microbiological method, in which the pigmentation ability is an important diagnostic feature. The method involves inoculation of the test material on a solid nutrient medium, incubating the crop under aerobic conditions at (37±1) °C for (16...18) hours. The resulting bacterial mass in the amount of one bacteriological loop is placed in 300 cm^3 of physiological solution and heated at (98...99) °C for (20...30) minutes, centrifuged at 12000 rpm for 30 seconds. To the supernatant, a dye for electrophoretic detection in an amount of 0.5 cm^3 and 20 cm^3 is added. 1.2 % of agarose gel on a TAE buffer with 10 cm^3 of 1 % ethidium bromide is needed in a 4×1 mm well [22, 23]</td></tr>
<tr><td>6</td><td>Staphylococcus aureus</td><td>The method involves filtering a sample in a volume of 50 ml through 2 or 3 filters to obtain isolated colonies, placing the filters on milk-yolk-salt agar and incubating at 37 °C for 24 hours. Next, the convex shiny colonies of white, pale yellow, golden in color are surrounded, surrounded by an iridescent with a pearly shine zone. If it is necessary to confirm the belonging of bacteria to Staphylococcus aureus, suspicious colonies are transferred to milk-yolk agar with plaques, microscopy, the plasma-coagulase activity is determined. In the presence of small gram-positive cocci, located in the form of grapes, and coagulated plasma give a positive response [24]</td></tr>
<tr><td>7</td><td>Micromycetes:
Aspergillus
Penicillum
Cladosporium</td><td>The method involves inoculation of water samples on a specific agar medium with subsequent incubation, counting and identification of the grown colonies. The procedure involves preparation of water samples, filtration through membrane filters, which are then applied to the surface of an agarized Saburo nutrient medium with dichlorane at a concentration of 2 μg/cm^3 (prevents the creeping of fungi, which makes it difficult to count individual colonies) [25, 26]</td></tr>
</table>

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To determine the effect of air pollution in the location of air conditioners on the quality of water from the air, studies were made of the content of various impurities in the air. The studies were carried out in parallel with the sampling of water on the day and time indicated above. For this purpose, a post-environmental mobile modernized ПЕП-1-1М (Russia) was used, designed for operational observations of surface air pollution, including measurements of mass concentrations and control of the content of pollutants such as CO, NO_2, NO, SO_2, H_2S, dust, hydrocarbons (saturated, unsaturated and aromatic), ammonia, ozone. ПЕП-1-1М is a device with alphanumeric and digital indication of the measured parameters on a liquid crystal display, with the possibility of storing up to 250 measurement results [27]. The measurements were carried out using gas analyzers, a dust analyzer and a chromatograph, which are part of the ПЕП-1-1М. Table 4 shows the methods and equipment used to determine the content of pollutants in the air in the location of air conditioners.

The mobile environmental post ПЕП-1-1М was also used to determine atmospheric conditions in the locations of air conditioners. In particular, using the automatic meteorological complex, which is a part of ПЕП-1-1М, measured the temperature and relative humidity of air, atmospheric pressure and wind speed. The condensate temperature and its quantity were also determined.

The environmental mobile post, as well as assistance in determining air pollution and atmospheric conditions, was provided by the analytical laboratory of the Department of Ecology and Natural Resources of the Odessa Regional State Administration of Odessa, Ukraine.

6. Research results

6.1. Atmospheric conditions under which a condensate of atmospheric moisture is obtained. Information on atmospheric conditions on the day of sampling condensate of atmospheric moisture, obtained experimentally, is given in Table 5.

Table 4

Methods and equipment for the study of air pollution*

Pollutant of atmospheric air	Method of determination	Range of concentration measurement, mg/m^3	Limits of measurement error: Reduced, %	Limits of measurement error: Relative, %	Equipment
1. Carbon oxide	The method assumes oxidation of carbon monoxide to dioxide, absorption of the latter with a weak alkali solution, followed by a conductometric determination of the amount of carbon dioxide	3…50	–	±20	Gas analyzer К-100 (Russia)
2. Ozone	The concentration of ozone in air is carried out by electric discharge method	0…0.50	±20	±25	Gas analyzer Р-310 А (Russia)
3. Ammonia	The mass concentration of ammonia in samples of atmospheric air is determined by the photometric method with sodium salicylate	0.02…5.0	±25	±22	Gas analyzer Р-310 А (Russia)
4. Dust	The dust load is monitored with a dust factor by measuring the content of free silicon dioxide	0…30	±20	±20	Dust Analyzer DACT (Russia), filters АФА-ВП-10 (Russia)
5. Nitrogen dioxide	Mass concentrations of oxide and nitrogen dioxide are determined by the reaction with the Griss-Ilosvay reagent using the photometry method	0…20.0	±23	±8	The device for sampling air type ПА-40М-1 (Russia), photometer photovoltaic КФК-3 (Russia)
6. Hydrogen sulfide	The method consists in absorbing hydrogen sulphide from the test gas with an acidified solution of zinc acetate and further spectrophotometric determination of methylene blue, formed in an acid medium by the interaction of zinc sulfide with dimethyl-l-phenylenediamine in the presence of ferric chloride (III)	0…0.3	±25	–	Gas analyzer СВ-320 (Russia), photometer photovoltaic КФК-2 МП (Russia) gas drum counter РГ-7000 (Russia), barometer-aneroid БАММ-1 (Russia)
7. Sulfurous anhydride	The method is based on fluorescent light emission by SO_2 molecules preliminarily excited by ultraviolet radiation	0…0.05	±25	±2	Gas analyzer ор СВ-320 (Russia)
8. Saturated hydrocarbons	Mass concentrations of saturated hydrocarbons C_{12}–C_{19} (in terms of total organic carbon) are measured by chromatographic method, based on the use of the properties of complex mixtures on a chromatographic column	0.2…1000	–	±20	Chromatograph with automatic sampling Кристал-5000.1 (Russia)

Note: * – the data are taken from [28–32].

Table 5

Experimental data on atmospheric conditions in places of water condensate extraction

Indicator	Conditioner No. 1: Midnight	Conditioner No. 1: Midday
Air temperature, °C	+17	+24
Atmospheric pressure, mm Hg	753	765
Relative humidity, %	82	75
Wind speed, m/s	3	6
Condensate flow, dm^3/h	0.25	0.4
Condensate temperature, °C	+12	+16
Indicator	**Conditioner No. 2: Midnight**	**Conditioner No. 2: Midday**
Air temperature, °C	+19	+26
Atmospheric pressure, mm Hg	750	770
Relative humidity, %	84	78
Wind speed, m/s	5	7
Condensate flow, dm^3/h	0.35	0.5
Condensate temperature, °C	+14	+19
Indicator	**Conditioner No. 3: Midnight**	**Conditioner No. 3: Midday**
Air temperature, °C	+18	+27
Atmospheric pressure, mm Hg	760	777
Relative humidity, %	88	80
Wind speed, m/s	5	7
Condensate flow, dm^3/h	0.45	0.59
Condensate temperature, °C	+12	+16

Analysis of the obtained results (Table 5) allows to note the following:

– increase in temperature and humidity of the environment, as well as increase in wind speed, causes an increase in the amount of water obtained from the air with the help of a domestic air-conditioner;

– the amount of atmospheric moisture condensed with the aid of Sensei FTB-25GR and Sensei FTI-25MR air conditioners (Table 1) at an ambient temperature of 17 to 24 °C, relative humidity ranging from 75 to 88 %, and wind speed ranging from 3 up to 7 m is an average of 7.5 to 12.5 dm^3/day.

6.2. Contamination of atmospheric air in places of water production. The results of determining the contamination of atmospheric air by various impurities in experimental conditioners are given in Table 6.

As can be seen from Table 6, high concentrations of carbon monoxide, hydrocarbons, and ammonia are observed in samples of air sampled from three experimental conditioners. In all air samples, the excess of the MPC value is based on the content of hydrocarbons, and the carbon monoxide content is close to the MPC value.

The high content of such pollutants in air samples can be explained by the fact that carbon dioxide and hydrocarbons are products of combustion of various fuels (coal, oil, natural gas, biomass), which uses transport and industrial enterprises [34]. In Table 2 it can be seen that there are a lot of transport highways and enterprises around the locations of experimental air conditioners. The reason for the high content of ammonia in the air can be the activity of the enterprise for the production and sale of ammonia, urea and fertilizers in the city of Yuzhny, Ukraine (Odessa Refinery), and the activities of rural farms.

Analysis of the experimental data given in Table 6. The following regularity are also revealed: the concentration of pollutants (carbon monoxide, ammonia, hydrogen sulfide, ozone) in all air samples is higher in the daytime, and the concentration of dust in the air is at night. This can be explained by the fact that it is during the day that traffic flows and the activities of enterprises are more intensive. During the night, on the contrary, more favorable conditions are created for the deposition of solid particles from the air and their accumulation in the surface layer of the atmosphere.

In terms of the content of nitrogen dioxide, sulfurous anhydride and saturated hydrocarbons in air samples, a similar pattern is not observed. Thus, for samples of air taken from air conditioners No. 1 and No. 2, the content of nitrogen dioxide, sulfurous anhydride and saturated hydrocarbons is higher in the daytime, and for air samples obtained at air conditioner No. 3 above at night (Table 6).

The increase in ozone concentration in the air during the day can be explained by the fact that in the lower atmosphere (up to 30 km from the surface of the Earth) ozone can additionally be formed as a result of photochemical reactions, in particular, in the interaction of nitrogen oxides and hydrocarbons [34]. As already noted above, in the daytime, the concentration of nitrogen oxides in the air increases. The concentration of hydrocarbons in the air also increases due to more intensive evaporation of water from the sea surface.

The increase in the concentration of hydrogen sulphide in the air during the day is explained by the more intensive industrial activity during this period. After all, it is a composite of gas emissions, in particular, chemical and oil refineries. In addition, do not forget about hydrogen sulphide, which is located in the anoxic layers of the Black Sea. The mixing of water in the sea can cause the rise of hydrogen sulfide to the surface of the sea and its entry into the atmosphere along with water splashes.

It is advisable to note that nitrogen dioxide is a product of combustion of fossil fuels containing nitrogen compounds and a product of photochemical oxidation of air nitrogen. It is a composite exhaust gas transport emissions, and its concentration is determined by the regime and organization of combustion processes. The greatest concentration of nitrogen dioxide is observed at the crossroads and car parks, where transport operates on interchangeable regimes. Also, nitrogen oxides fall into the air with the emissions of chemical industry enterprises, the production of mineral fertilizers, bacterial decomposition of silage. For sulfurous anhydride, it is the main representative of smoke emissions of boiler units [34]. Since exhaust and flue gases due to intensive traffic and the activity of enterprises are formed in the daytime more, in air samples the concentration of the constituents of these gases is higher precisely on the day.

Table 6

The content of pollutants in the ambient air

Conditioner	Time to sample air	The content of pollutant, mg/m^3							
		Carbon oxide, mg/m^3	Ozone, mg/m^3	Ammonia, mg/m^3	Dust, mg/m^3	Nitrogen dioxide, mg/m^3	Hydrogen sulfide, mg/m^3	Anhydride sulfur, mg/m^3	Saturated hydrocarbons C_{12}–C_{19} (in terms of total organic carbon), mg/m^3
No. 1	Midnight	3.2	0.018	0.054	0.0852	0.015	0.0012	0.006	1.1
	Midday	4.8	0.01	0.07	0.08	0.02	0.002	0.015	1.25
No. 2	Midnight	3.2	0.0018	0.054	0.0852	0.015	0.0012	0.006	1.1
	Midday	4.99	0.015	0.06	0.023	0.02	0.002	0.015	1.25
No. 3	Midnight	4.6	0.0015	0.042	0.099	0.12	0.0012	0.045	1.2
	Midday	4.99	0.015	0.06	0.044	0.033	0.0044	0.018	1.012
MPC (maximum single), mg/m^3*		5	0.16	0.2	0.5	0.085	0.008	0.5	1

Note: * – the data are taken from [33].

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For samples of air taken from the air conditioner No. 3, the reason for the increase in the content of NO_2, SO_2 and saturated hydrocarbons at the night could be an event in the seaport of large-capacity oil tankers. In addition, it could have been influenced by the clumps of cars on the parking lot of the Langeron beach at restaurants and entertainment establishments on weekends that were on the eve of the air sampling day.

It should be noted that a clear pattern of the influence of the height of placement of air conditioners and their remoteness from the coastal strip within the range of these values in the ranges in Table 2 was not found. Obviously, the decisive influence on the content of pollutants in the atmospheric air is detected by the distance from the experimental air-conditioners to the transport highways (automobile, sea and rail) and industrial enterprises. This is confirmed, in particular, by the chemical composition of the air samples taken from the air conditioner No. 3 (Langeron beach, Odessa, Ukraine). They have a high content of carbon monoxide, nitrogen dioxide, dust, hydrogen sulphide, sulfurous anhydride (Table 6).

6.3. Forecasting of microbiological contamination degree of water produced from air using a domestic air conditioner. Microorganisms are the most numerous group of living beings in nature. They are in the air, water, soil, plants, objects, products, on the surface and in the organisms of birds, animals and people. The properties of microorganisms are also very diverse. They easily adapt to power sources, in the majority – resistant to lack of moisture, temperature fluctuations, are able to multiply quickly.

In the literature [34, 35] it is noted that atmospheric air is an unfavorable environment for the propagation of microorganisms, since solar, ultraviolet and other radiation has a harmful effect on bacteria and viruses, for pigment formation. At the same time, sources of air pollution can be soil, ponds, people, animals, plants, various household wastes, and the like.

It is known that in the soil the vital activity of nitrifying, denitrifying and putrefactive bacteria, sulfur and iron bacteria, hydrogen-oxidizing (hydrogen), microorganisms, decomposing cellulose and pectin, actinomycetes, archaebacteria, mycoplasmas, mold fungi, yeast, opportunistic and pathogenic, zoopathogenic and phytopathogenic microorganisms [35]. The composition of the microbiota is heterogeneous and variable and varies depending on the type of soil, water, oxygen, weather and climate conditions and many other reasons.

Soil is the main pollutant of air by microorganisms. Microorganisms from the soil can enter the airspace of the room when it is being ventilated, be brought in with clothes and shoes of people, with vegetables and fruits, as well as pets. Especially dangerous are the bacteria of the *Escherichia coli* group (BECG) – the presence of *Escherichia coli*, *Salmonella*, *Shigella* and *Proteus*, as well as mold fungi and yeast, enterococci and pathogenic microorganisms.

Since all air conditioners in the experiment are located near the sea shore, the air can also be polluted by microorganisms that fall with water droplets are lifted by air masses from the sea surface. Sea air, in comparison with the air of settlements, is considered quite clean. At the same time, the authors of [35] indicate the possibility of the presence of pseudomonads, micrococci and enterococci in samples of sea air.

It should not forget about the human factor. After all, it is known that the air of closed, contaminated rooms, with poor ventilation, with a large population of people is more polluted by microorganisms than pure ventilated. In the premises, human microorganisms get from the surface of the skin, particularly dirty hands (staphylococci, micrococci, sarcin, actinomycetes, mold fungi, mycobacteria, yeast, streptococcus), from the mucous membranes of the respiratory tract (streptococci, staphylococci, actinomycetes, spirochetes and others).

Modern air conditioners are equipped with different air filters. In particular, the conditioners used in the experiment (Table 1) contain a mechanical filter and filters for air disinfection of various operating principles (plasma in conditioner 1 and antioxidant in air conditioners No. 2 and No. 3). According to manufacturers' information, such filters are effective against bacteria and viruses [16, 17], so it would be possible to assume that there will be no microorganisms in the water or their quantity will be insignificant. But there are a number of factors which influence makes this impossible. Firstly, it is the presence in the air conditioner of looseness in the housing, which allows free penetration of unfiltered air inside the equipment. Secondly, it is contact with the environment of the tube to drain the condensed moisture, and, as a consequence, the ingress of pollutants into it. Thirdly, the absence or non-observance of the sanitary treatment regimes of the internal working surfaces of the air conditioner and the conduits for draining the condensed moisture help to increase the number of microorganisms in the water.

Taking into account the above, it can be predicted that water samples are characterized by the qualitative and quantitative composition of a diverse microbiota. In addition, the increased content of carbon, nitrogen and sulfur compounds in the air (Table 6), as well as comfortable temperature and humidity (Table 5), constant access of oxygen to the air conditioner create favorable conditions for the life of microorganisms. To confirm these assumptions, experimental microbiological studies are performed.

6.4. The results of experimental studies of indicators of epidemic safety and other microbiological indicators of water from the air. The results of an experimental study of the microbiological indicators of the quality of water samples produced with the help of household conditioners are given in Tables 7, 8. In Tables 7, 8, the water sample number corresponds to the air conditioner number (according to Table 2).

Analysis of the research results of epidemiological safety indicators (Table 7) shows that water samples from air obtained with the help of all experimental conditioners are characterized by a significant excess of regulatory requirements [3]. In this case, the values of the quality indicators are worse than those for water samples obtained at noon. During this period of the day the air was more polluted and the temperature was not very high. A clear influence of other factors (design features of air conditioners, remoteness to the air conditioning from the sea coast, industrial enterprises, transport highways) on the indicators of epidemic safety of water in the experiment is not established.

Exceeding the standard for the total microbial number (Table 7) indicates the presence of a significant amount of mesophilic aerobic, facultative anaerobic microorganisms in the water, as well as the probability of opportunistic microorganisms.

Table 7

Indicators of epidemiological safety of water samples from air

Water quality index, unit of measure	Values of indicators						Standard
	Midnight	Midday	Midnight	Midday	Midnight	Midday	
	Sample No. 1		Sample No. 2		Sample No. 3		
Total microbial number, CFU in cm^3: – at 22 °C; – at 37 °C	 >300 >300	 >300 >300	 >300 >300	 >300 >300	 >300 >300	 >300 >300	 Not determined ≤100
General coliforms, CFU per 100 cm^3	$>3\cdot10^4$	$>3\cdot10^4$	$>24\cdot10^4$	$>30\cdot10^4$	$>3\cdot10^4$	$>3\cdot10^4$	Absent
E. coli, CFU per 100 cm^3	$>3\cdot10^3$	$>3\cdot10^3$	$>19\cdot10^3$	$>20\cdot10^3$	$>3\cdot10^3$	$>3\cdot10^3$	Absent
Enterococci, CFU per 100 cm^3	40	45	42	49	4500	4000	Absent
Ps. aeruginosa, CFU per 100 cm^3	170	1000	1000	1000	1000	17000	Absent

Table 8

Classification of bacteria in water samples from air

Type	Class	Order	The family and its share in the total number of bacteria	Species representative
Eubacteria	*Asporulales*	*Micrococcales*	*Micrococcacea* – 13.9 %	*St. aureas*
		Bacteriales	*Pseudomonadaceae* – 36.1 %	*Ps. aeruginosa*
			Enterobacteriaceae – 41.7 %	*E. coli*
Other bacteria – 8.3 %				

Confirmation of this is the conditionally pathogenic bacteria found in the water of the genus *E. coli* and *Ps. aeruginosa*. When bacteria were cultivated on special media and their differentiation, pathogenic bacteria of the genus St. aureus were found [1].

The microbiological studies made it possible to determine the structure of the microorganism community in water with their percentage. In particular, Table 8 shows the classification (according to [36]) of bacteria in water samples collected during operation of conditioner No. 1.

From Table 8 it can be seen that the most numerous in water samples are conditionally pathogenic bacteria of the families *Enterobacteriaceae* and *Pseudomonadaceae*. The characteristic features of representatives of these genera are that they are gram-negative rod-shaped bacteria and develop both under aerobic and anaerobic conditions. In particular, the bacteria of the family *Pseudomonadaceae* use oxygen as an electron acceptor under aerobic conditions, and in anaerobic – nitrates, which confirms their rapid development under conditions of water production from air [37].

Since the bacteria identified in the experiment (Table 8) are heterotrophic microorganisms, it can be assumed that autotrophs are present in the water samples [35]. Because for their development in the water, produced from the air with the help of air conditioners, there are good conditions. Air, cooled in air conditioners, is polluted by inorganic compounds of carbon, nitrogen and sulfur. When moisture condenses from the air, they enter the water and form a nutrient medium for the development of chemoautotrophs. The latter assimilate inorganic compounds: carbon for the synthesis of carbohydrates, ammonia or nitrate nitrogen for the synthesis of amino acids and the like. The main source of energy for such processes is chemical energy, which is obtained by chemoautotrophs as a result of oxidation-reduction reactions (oxidation of nitrogen nitrifying bacteria in ammonium compounds to nitrites and nitrates, oxidation of hydrogen sulfide to sulfuric acid sulfate bacteria). The presence of photoautotrophic microorganisms in water (they use solar energy as a source of energy) is unlikely, because when operating the air-conditioning unit of water accumulation and its transportation, light-tight containers and channels are inside.

Analyzing the data of Table 8 it can be noted that in samples of water from the air of pathogenic bacteria, including gram-positive bacteria of the genus *St. aureus*, is significantly less than the opportunistic bacteria *E. coli* and *Ps. aeruginosa*. This correlation between pathogenic and opportunistic bacteria can be explained as follows. Since the air conditioner works indoors periodically, conditions with nutrient deficiencies, low humidity, other pH, and enzymatic processes are created on working surfaces in contact with water. In addition, the bacteria *E. coli* and *Ps. aeruginosa*, produce secondary metabolites that have toxic and inhibitory activity against competing bacteria [35, 37]. Pathogenic bacteria are more sensitive and can't stand competition in the struggle for survival. The temperature factor also influences. Optimum temperature for development of *St. aureus* is a temperature regime in the range from +30 to + 37 °C. Under the experimental conditions, the condensate temperature ranges from +12 to +16 °C at ambient temperatures from +17 to +27 °C (Table 5).

It is important to note that the bacteria of the genus *E. coli* and *Ps. aeruginosa* are saprophytes. These bacteria decompose the substances of dead microorganisms under the action of hydrolytic enzymes. In addition to them, in the process of biological destruction of biomass, mold fungi and yeast are also involved. In experimental samples of water from air, obtained with the help of a domestic conditioner No. 1, the percentage of molds is determined. It is as follows: the fungi of the genus *Penicillium* are 19.4 %, the genus *Cladosporium* is 11.1 %, the genus *Aspergillus* is 8.4 %, and their associations are 19.4 %. In particular, it has been established that the fungi of the genus *Cladosporium* and *Penicillium* in the associations are found to be dominant. It should be noted that mold fungi of the genus *Aspergillus* are not dominant, but they are toxic, which provoke very dangerous for human life mycotoxins and, thus, mycotoxicoses.

For detection of all microorganisms in water produced from air using air conditioners, it would be necessary to perform still a significant number of experimental studies. This information is interesting, and in the framework of this paper this task is not raised. After all, from the analysis of the performed studies it is clear that it is dealed with a certain microbiocenosis. It contains autotrophic and heterotrophic, aerobic and anaerobic microorganisms. The qualitative composition of the microbiocenosis is formed under the influence of the environment and is regulated by the interrelations between microorganisms.

To develop a technology for the subsequent treatment of water produced from air, the main conclusion from the conducted microbiological studies is the conclusion about the mandatory disinfection of such water. The use of untreated water can cause infectious diseases, toxicoses and mycotoxicoses, which, as a rule, are accompanied by gastrointestinal disorders, violation of the work of individual organs and systems, and a decrease in immunity.

7. SWOT analysis of research results

Strengths. The studies carried out in the work show that atmospheric air and domestic air-conditioning can be an alternative source and means for obtaining water in regions with a deficit of fresh water. In addition, it is shown that the degree of air pollution and operating conditions of the air conditioner significantly affect the species and quantitative composition of the microflora of the condensate of atmospheric moisture. The strength of the work is that the necessity of obligatory disinfection of water, obtained with the help of domestic conditioners of split-systems, has been experimentally confirmed. The use of such process in water treatment technology will allow the use of atmospheric moisture condensate in both technical and drinking water supply.

Weaknesses. To select an effective method and rational technological regimes of disinfection of water from air, it is necessary to perform a number of studies. It is especially necessary to experimentally investigate the chemical composition of such water. This is important because individual components of water (for example, organic compounds or bromine), when interacting with disinfecting reagents of oxidative action can form toxic to humans compounds.

Opportunities. Information on sanitary and chemical indicators of water safety and quality will justify the choice of other processes for water treatment technology.

Threats. The condensate of atmospheric moisture is highly contaminated by microbiological indices. When developing technology to improve the quality of such water, understanding this alone is not enough. It is important to correctly determine the order of technological processes in the water treatment line. In this case, it is a question of the place of the water disinfection process in the technological line. Indeed, among the microflora present in the water from the air, are microorganisms capable of forming colonies on the surfaces of filtering materials of mechanical and sorption filters. As a result, the efficiency of water treatment processes is reduced, and the quality of water deteriorates. Therefore, in this case, the water treatment technology must begin in order to disinfect water. If the biological processes of water treatment are used in the technology, then in the previous disinfection of water there will be no need. In this case, the process of water disinfection will be the final stage of the technology.

8. Conclusions

1. The atmospheric conditions and the content of pollutants in the air in the places of obtaining water from it using household air-conditioners are determined. Condensates obtained during the day and night time of the day with change:

– air temperature – in the range from +17 to +27 °C;
– atmospheric pressure – in the range from 750 to 777 mm Hg;
– relative humidity of air – in the range from 75 to 88 %;
– wind speed – in the range from 3 to 7 m/s.

The condensate flow rates in these atmospheric conditions ranged from 0.25 to 0.59 dm^3/h. Concentrations of pollutants (in mg/m^3) in air samples varied within the following ranges during the day:

– carbon – from 3.2 to 4.99;
– ozone – from 0.0015 to 0.01;
– ammonia – from 0.042 to 0.07;
– dust – from 0.023 to 0.099;
– nitrogen dioxide – from 0.015 to 0.033;
– hydrogen sulfide – from 0.0012 to 0.002;
– sulfurous anhydride – from 0.006 to 0.045;
– saturated hydrocarbons – from 1.012 to 1.25.

2. It is shown that the degree of pollution of atmospheric air with carbon monoxide, ozone, ammonia, dust, nitrogen dioxide, hydrogen sulfide, anhydride sulfurous and saturated hydrocarbons is most affected by the remoteness of air conditioners from industrial enterprises and transport highways. The influence of the height of placement of air conditioners above sea level and their remoteness of the coastal strip are insignificant under the conditions under which the experiment is conducted.

3. In the experimentally obtained samples of condensates of atmospheric moisture, the indicators of epidemic safety are determined, and the percentage relationships between the families of bacteria and the genera of mold fungi are established. It is found that the microbial number, determined at 22 and 37 °C in all samples of water from the air, is more than 300 CFU in cm^3. The significance of other indicators of the epidemic safety of water (in CFU per 100 cm^3) varies in the following ranges: total coliforms – from $3\cdot10^4$ to $30\cdot10^4$; *E. coli* – from $3\cdot10^3$ to $20\cdot10^3$; enterococci – from 40 to 4500; *Ps. aeruginosa* – from 170 to 17000.

The structure of the community of bacterial families (in %) in samples of water from air is as follows: *Micrococcacea* – 13.9; *Pseudomonadaceae* – 36.1; *Enterobacteriaceae* – 41.7; others – 8.3. The percentage ratio in the group of molds is as follows: genus *Penicillium* – 19.4; genus *Cladosporium* – 11.1; genus *Aspergillus* – 8.4, and their associations are 19.4 %. It is also found that the fungi of the genus Cladosporium and Penicillium in the associations appeared to be dominant.

4. It is established that water from air, produced with the help of household air-conditioners, has a very low quality by microbiological indices. None of the investigated indicators of the epidemic safety of water from the air

does not correspond to the hygienic norms in force in Ukraine. Species composition of microorganisms is diverse. It contains autotrophic and heterotrophic, aerobic and anaerobic microorganisms. Microbiocenosis is formed under the influence of various factors (air pollution, operating mode and design features of the air conditioner).

5. It is impossible to use water obtained during the operation of wall conditioners for split-systems for drinking or technical needs. This is due to the presence in it of opportunistic and pathogenic bacteria, mold fungi and yeast. The use of such water can cause infectious diseases, toxicosis and mycotoxicosis, accompanied by gastrointestinal disorders, violation of the work of individual organs and systems, and a decrease in immunity. An obligatory process of improving the water as such must be its disinfection.

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ВЛИЯНИЕ УСЛОВИЙ ПОЛУЧЕНИЯ ВОДЫ ИЗ ВОЗДУХА НА МИКРОБИОЦЕНОЗ КОНДЕНСАТА

Представлены результаты теоретических и экспериментальных исследований влияния различных факторов на микробиоценоз воды из воздуха. Установлены закономерности между загрязненностью атмосферного воздуха различными примесями, а также особенностями эксплуатации настенных кондиционеров сплит-систем и рядом показателей микробиологического загрязнения воды. Показано, что вода, полученная из воздуха с помощью бытовых кондиционеров, характеризуется значительным микробиологическим загрязнением и без специальной очистки использовать ее для питьевых нужд опасно.

Ключевые слова: атмосферный воздух, бытовой кондиционер, качество воды, микробиоценоз воды из воздуха.

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CALCULATION OF PHYSICAL PROPERTIES OF FATS ON THEIR TRIACYLGYCLEROLE COMPOSITION

Проведено дослідження по отриманню жирових сумішей з заданими властивостями. Визначено залежність між фізико-хімічними показниками і концентрацією компонентів (триацилгліцеролів) суміші. Також визначено тріацілгліцерольний (ТАГ) склад переетеріфіцірованих жирів і отриманих в ході експерименту жирових сумішей. Доведено, що існує функціональна залежність між ТАГ складом і фізико-хімічними показниками.

Ключові слова: *тріацілгліцерольний склад, температура плавлення, температура застигання, рослинне масло.*

1. Introduction

The main component of fats (usually more than 95 %) is triacylglycerols. Triacylglycerol, and, consequently, fatty acid composition of fats is of great importance for the properties of food products containing fats [1, 2].

To obtain fatty products with specified physical-chemical and organoleptic properties, it is necessary to take into account the ratio of solid and liquid fats in the formulations of fatty foods. Physicochemical properties of fats affect the structure, stability, organoleptic characteristics and presentation of finished fat-containing products.

The composition of fatty foods for various food industries depends on many factors. The composition may be different, depending on the field of application, the process, the used equipment and many other features, and also depending on

