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DETERMINATION OF MAIN TECHNICAL PARAMETERS IN FORMING FOUNTAINS IN THE URBAN SPACES

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Abstract. The article deals with the problem of loss of the architects' skills and knowledge to combine the parameters of urban spaces with effective models of fountains, which are aesthetically and economically sound, perform scenarios conditioned by the city-planning situation, where the basic concept is aimed at improving the space. Based on specialized publications in the field of water supply engineering systems, including publications on hydraulics and hydraulic engineering, the physical and chemical capabilities of water are considered from a comprehensive perspective as methods that allow its integrated use for absorption and transportation of the mechanical and dissolved impurities, cooling of air streams from the atmospheric air. The fountain is highlighted as an object of urban planning, and water and its movement as the main element that makes it possible to control the hydrophysical processes that take place in space and time, during the operation of buildings and are aimed at improving the space. Water movement is provided by the fountain engineering. The author underlines the factors that dictate the formation of engineering in the space: resources provision; topographic and engineering-geological conditions; climatic and acoustic characteristics. It is considered how the engineering of fountains during operation provides interaction of air and water streams. Described in detail: schemes of engineering systems of water supply and drainage of buildings; features of operation; calculation of the main elements that dictate the formation of structures in space. The main technical parameters in forming fountains in urban spaces have been identified - there is a tool that will help in creation of the effective models of fountains and sustainable development of spaces over time.

Keywords: fountains, urban spaces, control of hydrophysical processes, engineering formation, calculation of elements, determination of parameters.

Introduction. One of the complex means for improving the microclimate and aesthetic qualities of the urban spaces, encouraging residents to stay and be active in space are water bodies, especially fountains. This experience has existed and developed since Mesopotamia, has been improving throughout human history. The study of the architectural development of fountains in settlements of the European countries, taking into account the philosophy of hydraulic society and worldview of the World History of water supply, sanitation, wastewater and stormwater and the experience of organizing spaces of fountains in Ukrainian settlements, demonstrates that each culture has formed their hydraulic systems and their fountains in the context of their specific social needs, climatic and geographical features, and national traditions. The structures have undergone multiple transformations, changed over time from water distributors into decentralized water supply systems, the basic concept of which was aimed at providing water to selected consumers or a limited group of residents into complex engineering systems that are perfectly integrated into the urban contexture, solve environmental, economic and social urban planning tasks by providing aspects of sustainable development of the urban spaces with fountains through time [1,2].

But modern architects have largely lost the skills and knowledge to combine the parameters of urban spaces with effective models of fountains, which are sound both aesthetically and economically, perform scenarios conditioned by the city-planning situation, where the basic concept is aimed at improving the space. Thus, fountains become the objects of urban planning, if to take into account not only the geometric parameters of space, but also the modeling of comfortable environmental parameters - temperature, humidity and noise, at the stage of formation of the detailed plans of territories and general layouts of urban spaces. Comfortable environmental parameters should be considered as a component in the architectural and planning organization of urban spaces with fountains and in planning their changes.

According to studies, the temperature, humidity and noise regime of the spaces with fountains creates a basic natural element which is mandatory. The water and its movement forms the architecture of water (free water surface) in the structure and the functional zone of interaction of the structure with space and inhabitants, or in other words the environment where the impact of fountains on the main social, recreational and communication activities of visitors is implemented. The movement of water (water flows) is provided by the fountain engineering during operation of the structure. Knowledge of physical properties of water such as evaporation, thermal conductivity, solubility (water as a solvent), viscosity, acoustics, reflectivity, etc. makes it possible to control the hydrophysical processes that occur in space and time [2,3]. Preliminary studies indicate that the intensity of the hydrophysical processes or in other words the intensity of the processes of interaction of air and water streams depend on the mode of operation of the structure.

That is, the purpose of this study is to determine the basic technical parameters in the formation of fountains in urban spaces. To achieve this purpose it is required to consider and describe in detail: the engineering of fountains, methods of its organization and the peculiarities of operation.

Analysis of research sources and recent publications. According to the «State Classification of Buildings and Structures» [4], the *engineering of fountain* is considered by the author in this study as a complex engineering system or organized set of elements (simpler engineering structures, pipelines, devices and structures, etc.), which are designed for collection, processing, transportation, if necessary, storage, distribution and provision of water movement in the structure. The main tasks performed by engineering during operation are aimed at correction of the microclimate, increasing comfort and adapting urban spaces to the effects of climate change.

The methods of arrangement of the engineering of fountain in urban spaces are considered in the monographs by P.A. Spyshnov [5,6]. The author presented in detail: schemes of engineering systems of water supply of the structures; hydraulic calculation of water streams (jets) that form the architecture of water in the catchment area; hydraulic calculation of the catchment area. Depending on the sculptural design and composition of water streams (jets), P.A. Spyshnov divides fountains into six main types and develops a typology that is popular among the architects and engineers today. Research is fundamental, with detailed coverage of all stages of fountain formation. Now, the presented developments need to be clarified, because the mentioned works date back to the 50s of the last century.

Based on the methods offered in the research of the authors of specialized publications in the field of water supply system engineering, including publications on hydraulics and hydraulic engineering of the scientists such as L.D. Berman [7], L.A. Vitman [8], P.A. Grabovsky et al. [9], P.A. Grabovsky and G.M. Larkina [10], V.V. Goncharov [11], M.M. Gryshyn [12], Isachenko, V.I. Kushnyrev, [13], A.N. Postnikov [14], T.V. Odrova. [15], R.R Chugaev [16], A.F. Shabalin [17] – the physical and chemical capabilities of water are considered from a comprehensive perspective as methods that allow its integrated use for absorption and transportation of mechanical and dissolved impurities from the atmospheric air and at the same time serve as a cooler of air streams.

The researchers S.I. Borovyk [18], I.P. Kozyatnyk [19], H. Jin et al. [20], L. Yang et al. [21], M. Robitu et al. [22], K. Setaih et al. [23], G.J. Steeneveld et al. [24], N.I. Syafii et al. [25], F. Taheri [26], and F. Xue et al. [27] note that the health of the inhabitants of settlements depends on the characteristics of urban space and the state of the air.

Similarly, in the study, the author pays attention to the works, which consider only some, but important aspects of the design and organization of fountain engineering. P.N. Zhurakovsky et al. [28], A.M. Manuilov et al. [29,30], M.B. Manuilov et al. [31], A.V. Martynov et al. [32] devoted their works to such research.

The analysis of water streams by the nature of movement, geometric shape and acoustic characteristics and research of the method for control of the impact of fountains during operation on the acoustic characteristics of urban spaces are disclosed by the author in the report «Fountains as a tool for environmental noise management in the urban environment» [33], presented at the IX International Scientific Conference ArCivE '2019 Varna, Bulgaria.

The base material and results of research. In order to determine the main technical parameters in the formation of fountains in the urban spaces, we consider first of all the main factors that dictate the organization of engineering of the structures and features of its operation.

According to the State Standards of Ukraine DSTU-N B B.1.1-27:2010 Construction climatology [34], each urban space or urban situation of the settlement belongs to a certain architectural and construction climatic subregion with its climatic conditions caused by the vertical zonality, features, local air circulation and has its own characteristics. Among the main factors that dictate the organization of engineering of fountains in space, we should highlight the *urban* and *aesthetic*. The urban factor consists of the components such as:
- resources provision for the implementation of the planned measure (Fig. 1 a);
- urban situation and its conditions (topographic and engineering-geological) (Fig. 1 b) and characteristics (climatic and acoustic) (Fig. 1 c).

The aesthetic factor influences the integrated introduction of fountains into the structure of urban space. The concept of integrated introduction is that «the formed structure should create harmony with the surrounding space». This is a prerequisite that makes it possible to create an artistic and aesthetic integrity of the perception of the structure with urban space.

The resources provision for the implementation of the planned measures (Fig. 1a) is primarily a source of water and energy supply of the structure and the presence of sufficient space in the structure of the urban situation for the organization of the structure [35,36].

Favorable topographic conditions of the area make it possible to form the natural circulation of urban spaces with fountains and use the fall of the terrain for repeated water operation in a complex of structures located at different levels. Engineering and geological conditions are characterized by the soil type, the presence of groundwater, the degree of subsidence, etc.

The climatic characteristics of the urban spaces or urban-related situation include:
- atmospheric air temperature T_a, ^{0}C (average, absolutely minimum, absolutely maximum);
- relative humidity φ,%;
- wind characteristics, W: average speed V_w, m/s, predominant direction; frequency;
- intensity of thermal radiation from hot surfaces $T_{surface}$, ^{0}C i J, W/m^2.

The wind or progressive air currents that occur in the atmospheric air due to the difference in temperature and pressure over different parts of the earth's surface have primary influence on the state of atmospheric air and changes in the characteristics of urban space. The wind is characterized by: average speed V_w, m/s, predominant direction, frequency. The progressive air streams set the movement of air streams within space and ensure the performance of hydrophysical processes that occur during the operation of structures [37-39].

The movement of air streams can be carried out in vertical and horizontal directions. In the horizontal direction, the movement of air streams is caused by the pressure difference in different parts of the atmosphere. In the vertical direction, the movement of air streams is due to the temperature difference in the upper and lower layers of atmospheric air. At low wind speeds or adverse directions, the performance of hydrophysical processes that occur during the operation of the structure deteriorates, and the ability to perform all the planned tasks becomes limited. At the temperature of atmospheric air T_a, ^0C above the temperature of the free surface of water in the structure T_{AW}, ^0C, there is a process of heat transfer by collision, which results in cooling of atmospheric air (decrease in temperature, increase in humidity) and transfer of part of its heat to the water surface. Provided that the temperature of atmospheric air T_a, ^0C, located above the surface, is higher than the surface temperature of water T_{AW}, ^0C:

$$T_a > T_{AW}, {}^0\mathrm{C},$$

and air streams are not mobile, i.e. wind speed is zero (V_w = 0, m/s), there are convective currents as a result of changes in temperature and moisture content of air streams near the water surface (Fig. 2 a). In case of changes in temperature and moisture content of air streams, their specific weight and a direction of movement from horizontal to vertical changes, as a result drier air streams arrive to a water surface. The described phenomenon is called free movement of air streams or *natural convection.*

According to the researches published by L.D. Berman [7], V.V. Goncharov [11], V.P. Isachenko, V.I. Kushnyrev, [13], A.N. Postnikov [14], T.V. Odrova [15], A.F. Shabalyn [17], the natural convection increases the intensity of the heat transfer and evaporation processes.

In the functional zone of interaction (Fig. 1), which is formed by the structure during operation, the air streams are increasingly in a state of forced motion (Fig. 3 a) under the influence of the factors such as:
- wind, *W*;
- ejection action from the dynamic change of water streams.

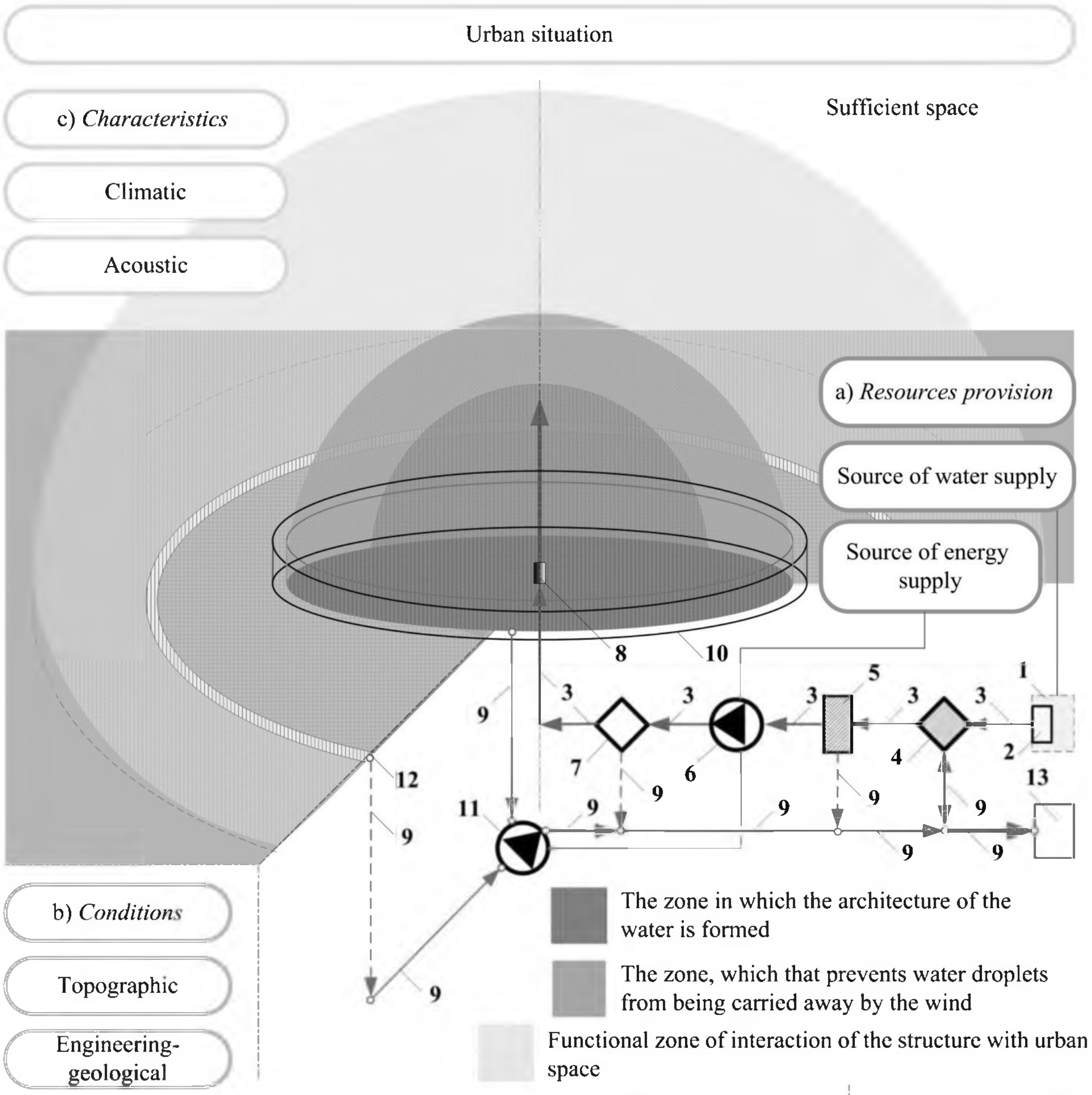
Following the researches by L.D. Berman [7] and V.V. Goncharov [11], in order to increase the intensity of interaction of air streams and water surface (Fig. 2 c: 5), at a given wind direction, when forming the architecture of water it is necessary to provide extended air corridors between individual water streams (Fig. 2 b). According to the researches described in the work by V.V. Goncharov [11, p. 43], the width of the air corridors can vary within 2.5 - 5 m, depending on the size and shape of the catchment area (if any), wind speed and other interdependent factors. Inflowing air streams come into contact with the water surface, resulting in interaction between air streams and the water surface (Fig. 2 c). The intensity of the interaction of air streams and water surface depends on:
- speed of air streams relative to the water surface;
- composition of air streams and the composition of water used in the engineering of the structure.

The specified intensity of the interaction of air streams and water surface affects:
- characteristics (temperature, humidity, chemical composition, etc.) of air streams;
- characteristics (temperature, chemical composition, etc.) and the amount of water used in the engineering of the structure.

Consider the situation when at a given wind direction the extended air corridors were not formed between individual groups of water streams during the formation of water architecture (Fig. 3 b).

According to the research by G.I. Bolotov [38, p.539-540], O.S. Bezlyubchenko [37], L. Kleerekoper et al. [40] and F. Xue et al. [27], under the action of wind, the air stream decreases when approaching the obstacle, thereby creating a positive pressure (support zone) on the windward side and a negative pressure (shadow) on the leeward side. In this case, the air stream (Fig. 3 b: 1), which flows around the water surface (Fig. 3 b: 2) from above and from the side, accelerates, thereby compensating and reducing the area of its intersection, which was caused by the obstacle. Inflowing air stream is divided at about 2/3 of its height, when encountering an obstacle in the form of a water surface (Fig. 3 a,b).

If the obstacle is located in an open area, the stream distribution is in the center of the windward part. Due to the inertia, which deviated from its original trajectory, the air stream, bypassing the water surface, tends to maintain a more or less straight trajectory. Therefore, within a certain space on the leeward side of the obstacle, a zone of negative pressure is formed. In this zone, small air vortices are formed, and the movement of an air stream has turbulent character.



d) *Engineering of structure*:
1. Source water supply.
2. Water intake system.
3. Engineering system water supply.
4. System water treatment from the source.
5. Regulating tank, that is designed to receive circulating water.
6. Pump system water supply.
7. System circulating water treatment.
8. Nozzle or nozzle system.
9. Engineering system water drainage.
10. Catchment area.
11. Pump system water drainage.
12. External catchment system.
13. System water drainage of the settlement.

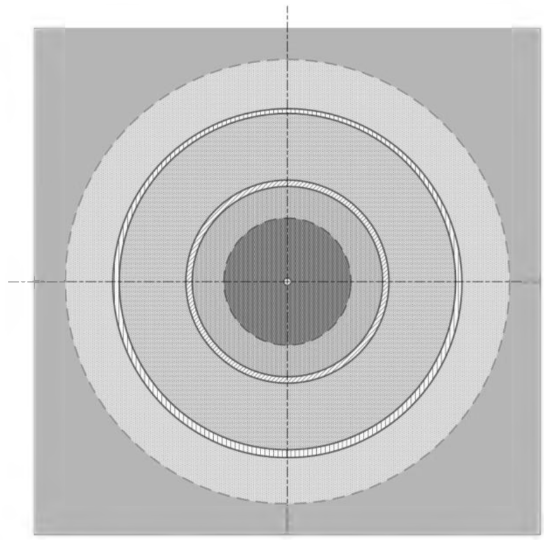


Fig. 1 The influence of urban planning factor on the peculiarities of the organization of fountain engineering in space (illustration: O. Tserkovna)

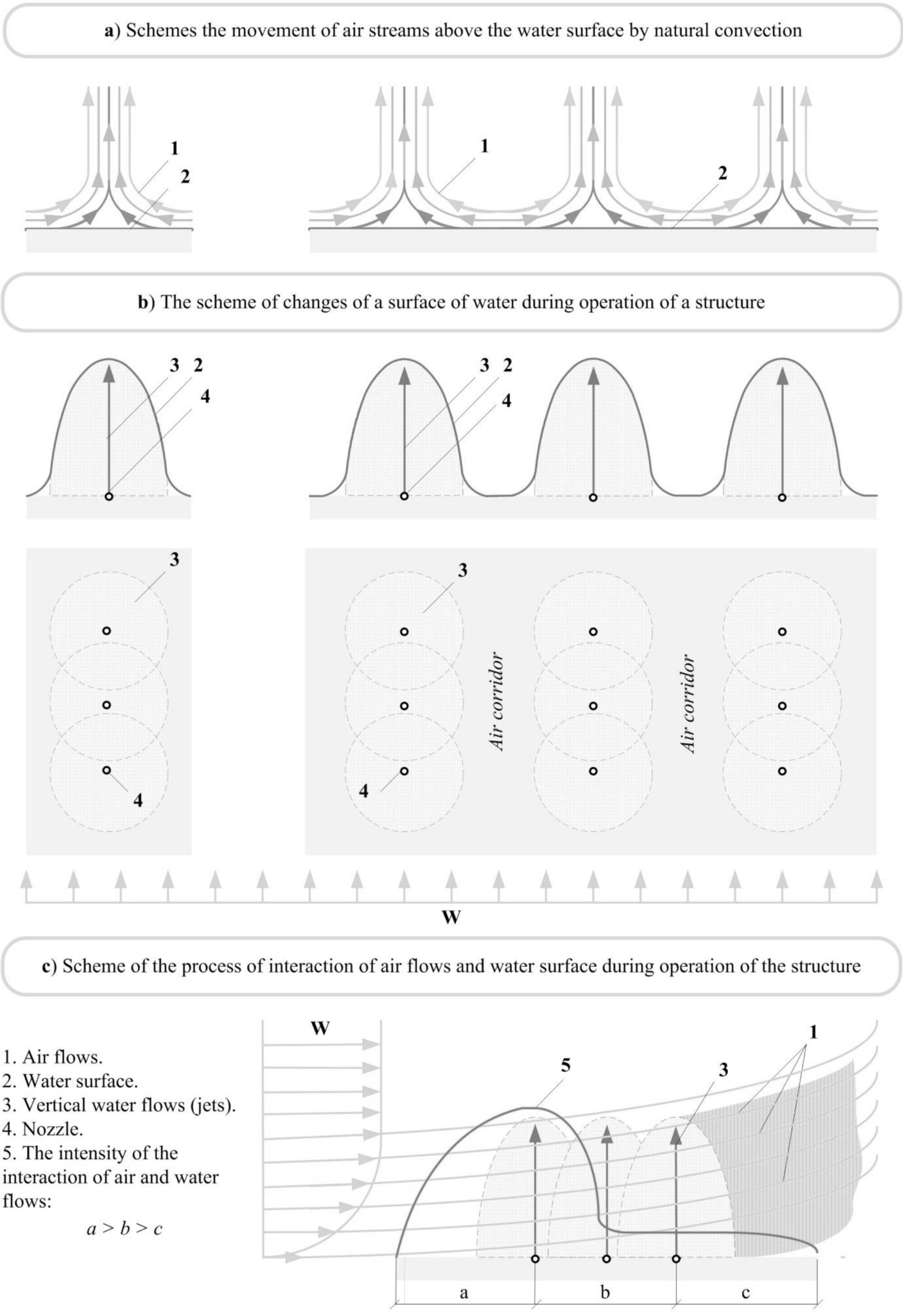
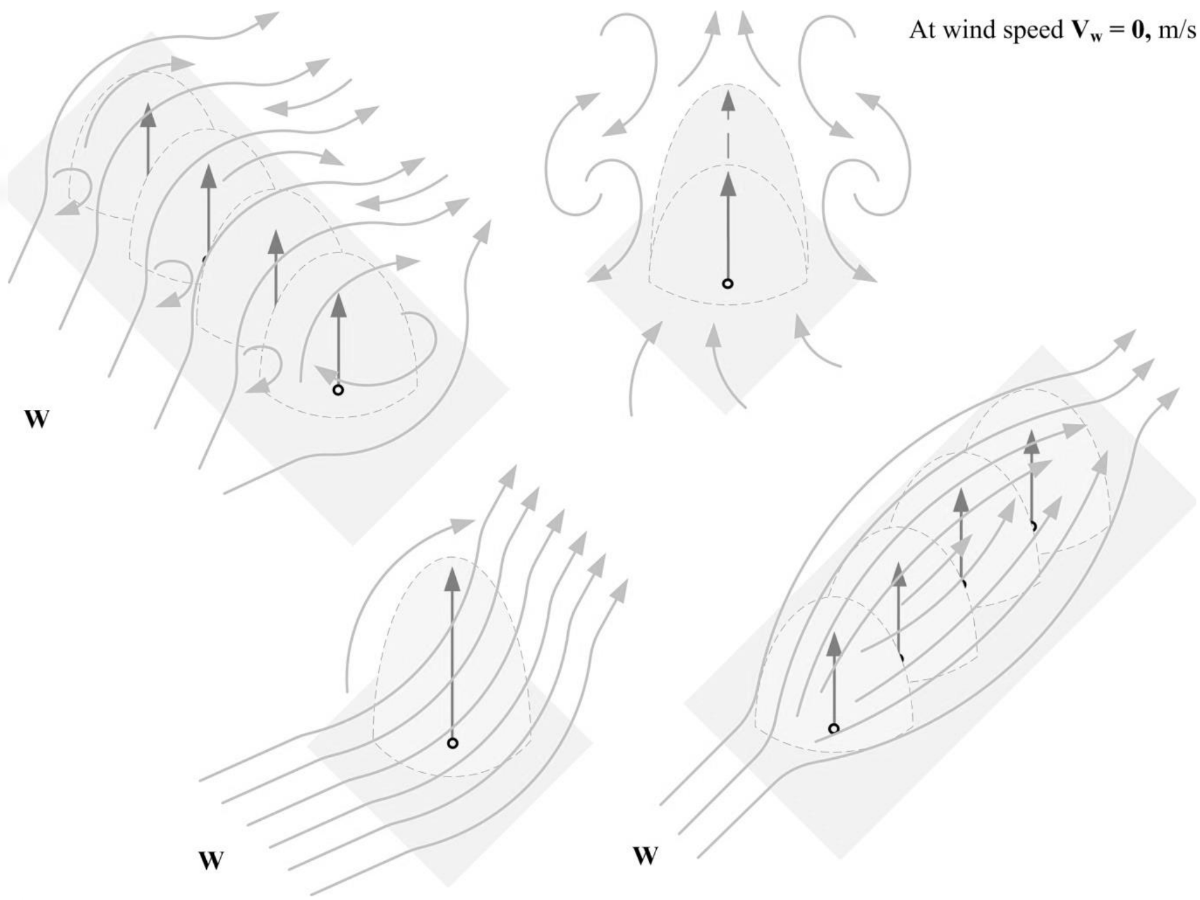


Fig. 2 Schemes of the interaction of air streams and water surface during operation of the structure (illustration: O. Tserkovna)

a) Variants of schemes process of interaction of air flows and water

At wind speed $\mathbf{V_w = 0}$, m/s



b) Scheme of the process of interaction of air flows and water surface during operation of the structure

1. Air flows.
2. Water surface.
3. Vertical water flows (jets).
4. Nozzle.
5. The intensity of the interaction of air and water flows:

$a < b > c$

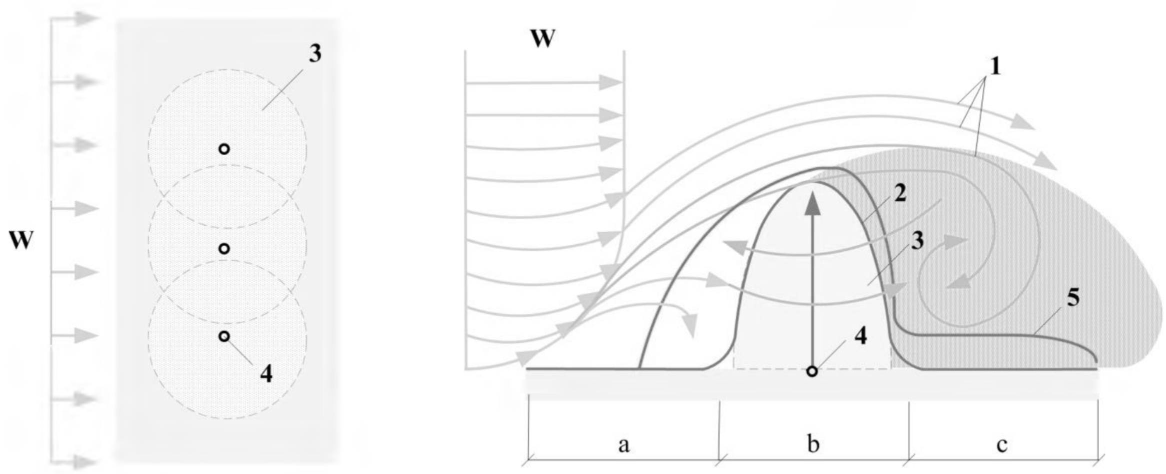


Fig.3 Variants of schemes of the interaction of the air streams and water surface during operation of the structure (illustration: O. Tserkovna)

As a result, in the functional zone of interaction of the structure with space, with a linear, elongated and significant shape of the structure in plan, a wind regime is formed which differs from the wind regime of the surrounding space and is characterized by accelerated wind speeds and turbulence zones. Accelerated wind speeds in combination with areas of turbulence of air steams causes discomfort to visitors to the space, has a negative impact on vegetation and nearby buildings.

O.S. Bezlyubchenko [37] and I.P. Kozyatnyk [41] recommend assessing the aeration regime of the urban space and making aeration maps as one of the tools for the formation of climatic characteristics.

While in motion, the air streams constantly change their composition, are contaminated with impurities of harmful substances: greenhouse gases, dust, and other waste products of residents. Ensuring the complete absence of pollutants in the air is an unrealistic task. Similarly, under the action of wind or in interaction with traffic flows, the pollutants, being in a constant suspended state, enter the catchment area of the fountain and the external catchment system (Fig. 1 d: 10, 12). Therefore, reducing the concentration of pollutants in the air of space and removal of substances from the water, the concentration of which violates the maximum permissible norms established by the current DSanPiN 2.2.4-171-10 Hygienic requirements for drinking water intended for human consumption [42] become priority tasks in determining the main technical parameters that dictate the formation of fountains in the spaces of settlements. Following the conclusions made in their research, A.M. Manuilov et al. [29,30], M.B. Manuilov et al. [31], A.V. Martynov et al. [32]:
- volume and quality of water used in the engineering of the structure has impact on the composition and characteristics of atmospheric air within space.

In nature, everything is interconnected, therefore, the climatic characteristics of the urban space also influence on the formation of fountains, more precisely the volume of water Q_f, m^3, which is used in the engineering of the building. The drier the climate, the higher the water consumption in engineering and the higher the water consumption of the fountain. According to DSTU-N B B.1.1-27:2010 Construction climatology, [34, p.3, Table 1], the absolute maximum air temperature (from 39 ^{0}C to 41^{0}C) in the summer with a minimum rainfall (from 400 to 500 mm/year), relative humidity φ less than 65% and an average wind speed of 4 to 6 m/s are climatic indicators (characteristics) of the South-Eastern (Steppe) architectural and climatic region of Ukraine. The climatic region is characterized by the highest level of insolation, greater aridity and dry hot winds, which dramatically increase water evaporation. Therefore, in this area the water consumption in the structure is much higher than in other areas with less arid climates.

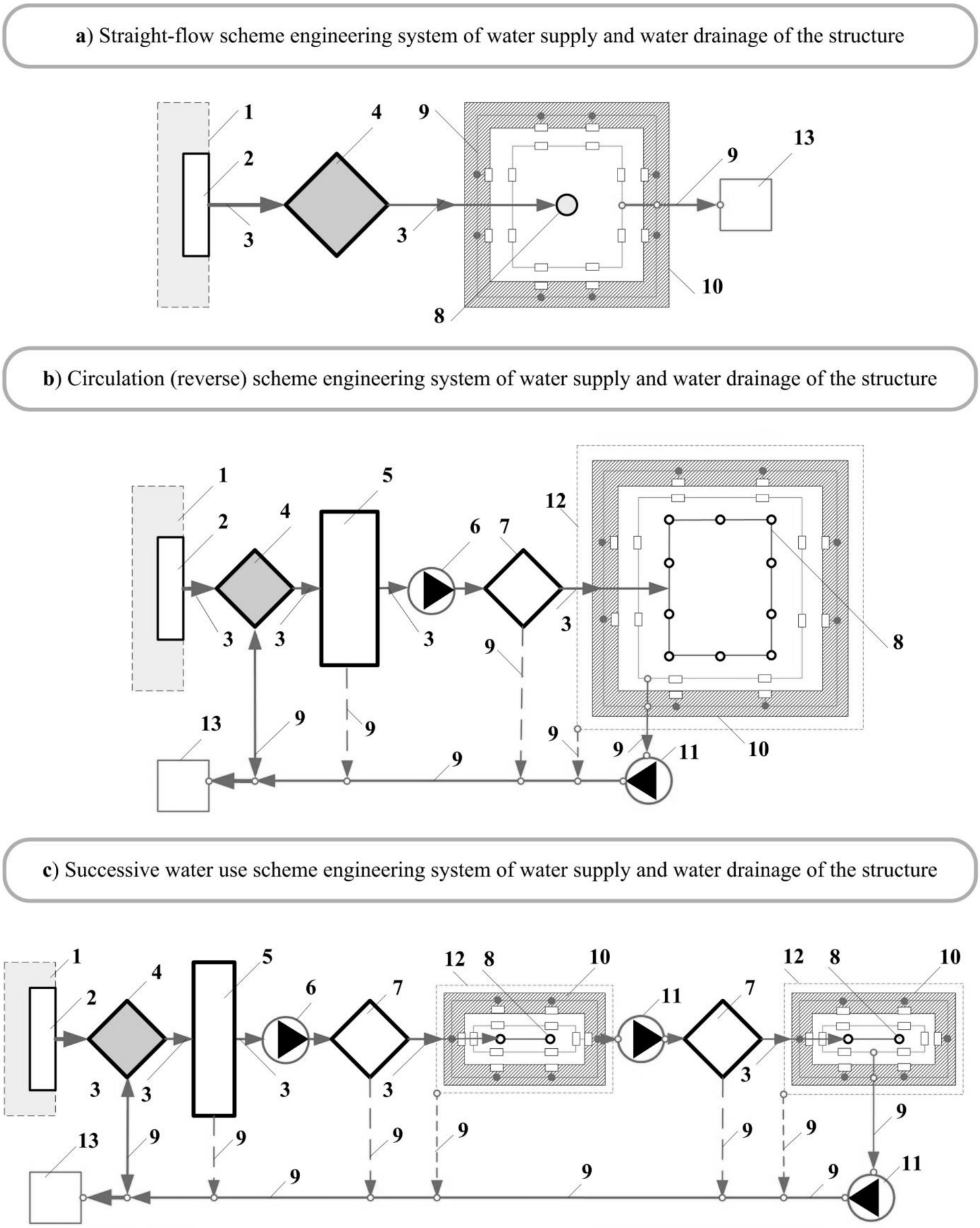
According to the study [32], the acoustic characteristics of the urban space or noise level, $L_{A\ urban}$, dBA is determined by the composition of natural, man-made and biogenic sounds of the space and depends on planning solutions (density and number of storeys in the buildings, distance of transport, rail, air or water traffic from the space, etc.).

During the operation of the structure, the water streams in uniform and non-uniform motion generate *hydraulic noise* $L_{A\ hydro}$, dBA - unstable or random acoustic oscillations. Acoustic oscillations have different noise levels, and can change over time depending on changes in the operation of structures. The demand to take into account the acoustic oscillations of hydraulic noise in the formation of structures in space is based on the fact that unpleasant noise as an adverse physical environmental factor harms the health of residents and reduces their efficiency in the area of acoustic impact.

Depending on the concepts and intended purpose of the fountain, the resources provision (Fig. 1 a), conditions (Fig. 1 b) and the characteristics of the space (Fig. 1 c), the scheme of the engineering system of water supply (WS) and water drainage (WD) and feature its operation A_f are determined. The scheme of the engineering system of WS and WD of the structure clearly reflects the relationship of the elements involved in the operation of the fountain. The elements of the scheme count on a clear operation in the general chain and the possibility of complete removal of water for the period of conservation (termination of operation) of the structure [6, p.204].

The Figure 4 demonstrates the basic schemes of the fountains' WS and WD engineering systems. Taking into account the features of space, a certain degree of necessary modifications of the given schemes is possible. Adopted schemes differ by the method of using water in the technological process and can be [10,12,16,17]:
- *Straight-flow scheme* (Fig. 4 a). In the straight-flow scheme, the water from the source (Fig. 4 a: 1) is received by the water intake system (Fig. 4 a: 2), undergoes the process of water treatment (Fig. 4 a: 4), then is transported by the WS engineering system (Fig. 4 a: 3) to the nozzle or nozzle system (Fig. 4 a: 8). The system of nozzles forms water streams, which in turn create the architecture of water and is destroyed under the influence of gravity. When water streams are destroyed, there is a process of water droplets formation, which are collected by the catchment area (Fig. 4 a: 10) and/or the external catchment system (Fig. 1 d: 12), from which the water is transported by the WD engineering system of the structure (Fig. 4 a: 9) to the universal WD system of the settlement (Fig. 4 and: 12). According to the scheme, the water is used in the technical process once. The results of retrospective and graphoanalytical analysis of structures from their origin to the present day demonstrated [2]: straight-flow scheme in the WS engineering system of structures was mainly used at the stages of *origin, development and expansion* of structures, subject to sufficient capacity of a natural source, and is characterized by ease of operation and maintenance.
- *Circulation (reverse) scheme* (Fig. 4 b). In the circulation scheme of the WS engineering system of the structure, the water from the WS source is taken for the first filling of the system and to compensate for losses (Fig. 4 b: 1). After passing the technological process, which was described in the previous scheme, the water is transported by the WD engineering system of the structure (Fig. 4 b: 9) for water re-treatment (Fig. 4 b: 4), and then returned to the process. The advantage of the circulation scheme compared to straight-flow scheme in a significant reduction in the volume of water taken from the source and discharge of water into the WD systems of the settlement. Given the identification of the catchment area of the structure with the source, a natural and/or artificial reservoir, the water circulation in the WS engineering system of the structure affects the ecology of the reservoir. With a reasonable arrangement of the engineering of structures, the circulation and aeration of water is improved. The disadvantages of the circulation scheme include the complexity and high cost of technologies and equipment, requirements for control and regular maintenance during operation of the structure. Adhering to the retrospective and graphoanalytical analysis of structures from their origin to the present day [2], the circulation scheme in the WS engineering system of fountains appeared at the stage of *technologization* in the twentieth century, after the emergence and development of new technologies for water lifting and transportation - pumping systems (PS). The PSs provide transportation of water from the source, water circulation in the scheme of the WS engineering system of structures, water supply to the nozzle system under the necessary pressure, and return of water to the technological process [28].
- *Successive water use scheme* (Fig. 4 c). The successive water use scheme is applied in the WS engineering system of the complex of structures.

After use in one technological process, the water is delivered for successive use in the next process, then, after water treatment, it is returned for reuse as in the circulation scheme, or can be discharged into the universal WD system of the settlement as in the straight-flow scheme (Fig. 4 c: 12). The advantages of the successive water use scheme in the WS engineering system: smaller volume of water taken from a source and discharged in local WD systems of the settlement; lower productivity of treatment systems, but higher cost due to additional equipment and length of water distribution networks, complexity and high cost of technologies and equipment, requirements for control and regular maintenance during the operation of the structures. Adhering to the retrospective and graphoanalytical analysis of fountains from their origin to the present day, the successive water use scheme in the WS engineering system appeared in the XV century at the stage of *expansion* of structures [2].



1. Source water supply.
2. Water intake system.
3. Engineering system water supply.
4. System water treatment from the source.
5. Regulating tank, that is designed to receive circulating water.
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8. Nozzle or nozzle system.
9. Engineering system water drainage.
10. Catchment area.
11. Pump system water drainage.
12. External catchment system.
13. System water drainage of the settlement.

Fig. 4 Schemes of engineering systems of the water supply and drainage in fountains (illustration: O. Tserkovna)

The WS and WD schemes of the structures are selected on the basis of comparison of possible variants of implementation and comparison of the technical and economic indicators. To ensure sustainable development of the fountain in space and time, and to obtain water of guaranteed quality and quantity, the adopted scheme of WS and WD engineering system shall be cost-effective, efficient and provide the building with the estimated water flow Q, m^3/h, at any time period of operation. The structures, materials and equipment that are accepted for the formation of fountain engineering shall ensure the smooth reliability of its operation throughout the life cycle (estimated period) and repair.

As noted earlier, for natural reasons, the water in the engineering of the structure is consumed unevenly both during the year and within the day (Fig. 5). The graph of the dependence of water consumption on the period of structure's operation (within a year) demonstrated that in hot and dry periods the water consumption in the engineering of the facility is higher (Fig. 5 a) than in spring and autumn, and in winter, in most cases, the structures terminate their life cycle. Similarly, during the day the water consumption for evaporation (Fig. 5 b) is usually higher than at night, and in the morning due to the increase in atmospheric temperature. When designing, the engineering of the structure is based on three modes of operation (Fig. 5 c):
- minimum $A_{f\,min}$,
- medium $A_{f\,mid}$,
- maximum $A_{f\,max}$.

Based on the uninterrupted water supply for the estimated period of operation, the scheme of WS and WD engineering system of the structure shall be calculated and designed for the maximum water consumption mode Q_{max}, m^3/h at the maximum operation of structure $A_{f\,max}$ (Fig. 5 c). All accepted elements in the scheme shall correspond to this mode. With medium $A_{f\,mid}$ and minimum $A_{f\,min}$ mode of engineering operation, part of the system power is not used. The technical and economic indicators of such a system are low. It is possible to improve the performance of the adopted scheme of the engineering system of the structure, if some elements are calculated for the medium mode $A_{f\,mid}$ of operation of the structure, and regulating tank - the tank for receipt of used water is included in the scheme (Fig. 4 b, c: 5). The elements in the scheme of the WS engineering system of the structure to the tank (in the direction of water movement) will operate in the medium mode of operation of the structure. After the tank, any mode of operation of the elements is possible - from the maximum $A_{f\,max}$ to the minimum $A_{f\,min}$ mode of operation of the structure.

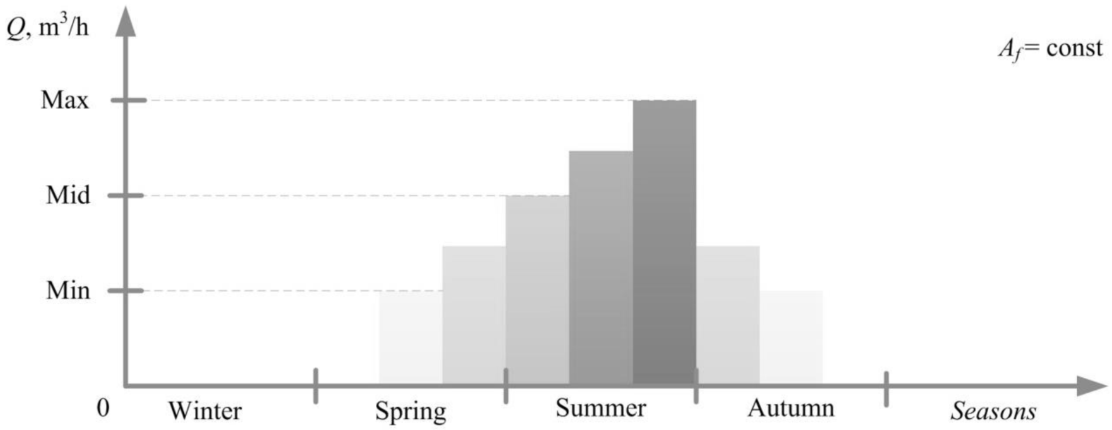
The selection of the scheme of the WS and WD engineering system of the structure is significantly influenced by the source. Adhering to the retrospective and graphoanalytical analysis of the structures from their origin to the present day and according to the DBN B.2.5-7:2013 Water supply. External networks and structures [43], the WS sources can be:

a) natural:
- surface (rivers, lakes, ponds, reservoirs, seas),
- groundwater (water from water-bearing layers, lakes);

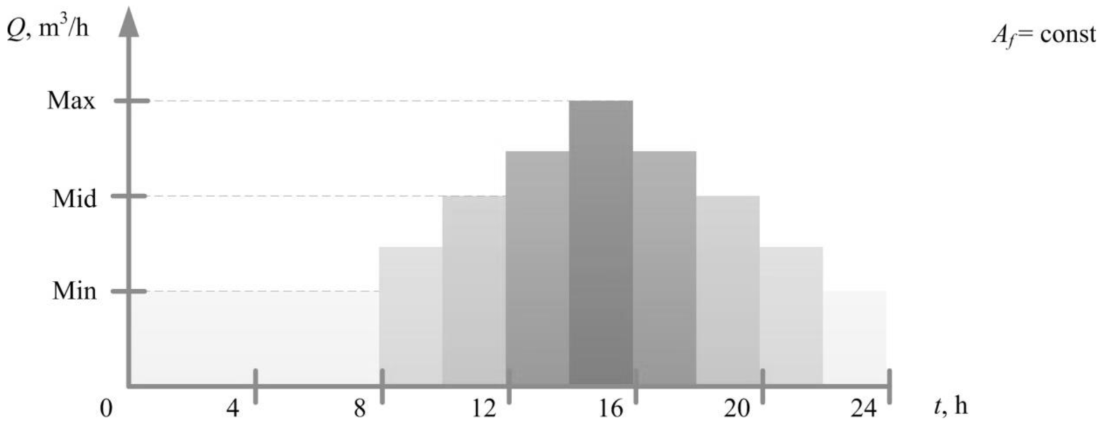
b) artificial:
- reservoir, canal, others, which in the course of design are identified with the bed (pool) of the structure (with specification of the possibility of compensation for water consumption in the reservoir due to natural or alternative power sources of the reservoir);
- external water supply system (centralized, group, decentralized: local or territorial);

c) alternative - sources that can compensate for water consumption in the engineering of the structure, and at the same time they do not belong to water resources, for example, for WS of the structure the recycled water from enterprises can be used in accordance with their quality of current sanitary standards. Similarly, after the necessary water treatment, the atmospheric water and water from drainage systems are used for the WS of the structure. It is possible to use several sources with different characteristics [1].

a) Graphs of dependence of water consumption Q, m^3/h from the period of operation (work) of the engineering structure (within a year)



b) Graphs of dependence of water consumption Q, m^3/h from the period of operation of the engineering structure (within a days)



c) Graphs of dependence of water consumption Q, m^3/h from the period of operation A_f of the engineering structure

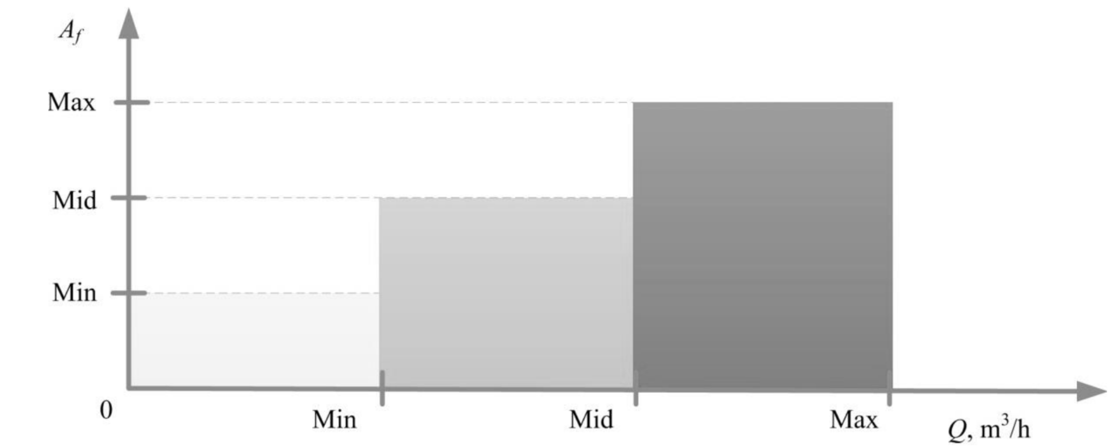


Fig. 5 Graphs of dependence of water consumption in fountains on various factors (illustration: O. Tserkovna)

When choosing the source of WS of the structures, in the first place, the requirements of current sanitary and technical standards for water quality or in accordance with DSTU 4808:2007 Sources of centralized drinking water supply [44] are taken into account. The water quality requirements are characterized by the content of mechanical impurities and organic substances, dissolved mineral salts and gases. Knowledge of water characteristics when choosing the WS source of the structure is paramount, because prior to meeting requirements for sanitary regulations governing water quality in the structure the water treatment may require complex and expensive measures that can be avoided with a better choice of WS source of the structure.

Depending on the receipt technology, the following types of water are found in the water supply of structures:

a) treated water means the water produced from water received from natural (surface or groundwater) or any other alternative sources of water supply, by purification and/or disinfection;

b) untreated (natural) water means the water received directly from natural (surface and/or underground) sources of WS, which in all respects meets the requirements of sanitary norms without their purification (except for clarification) and disinfection.

The water losses in the engineering of the structure are compensated by adding of the appropriate amount of fresh water to the system from the source of the structure. With additional water, the impurities enter the system, which can cause serious operational difficulties, which are mainly related to the contamination or corrosion of surfaces and "blooming" of water - the appearance of organic matter in the catchment, which significantly reduces the aesthetic properties of the fountain [7,9].

To remove or reduce the concentration of pollutants in the water which enter the pool with atmospheric air and additional water, and to obtain quality water in the WS engineering system, the *water treatment system* from the source and *recycled water treatment system* is important [10, p. 8]. The main purpose of water treatment: to ensure high and stable water quality in the engineering of the building in terms of hygiene, safety and aesthetics, taking into account the requirements that exclude any harm to the health of residents. The water treatment technology and the performance of the equipment applied shall reliably ensure the conditions under which the water in the system will be in a state of stable equilibrium between purification and pollution, regardless of the load, climatic conditions and other factors. As a result of the water treatment process, the quality of water used shall meet epidemic safety standards for fungal, viral, bacterial and parasitic diseases, organic and other contaminants partially or completely dissolved in it. The concentration of substances that cannot be completely removed from the water during the water treatment process is maintained within the regulatory indicators by feeding with fresh treated water.

To achieve stable water quality, a set of measures shall be taken, which include:

- organization of water circulation in the bed of the catchment basin (if any in the scheme);
- mechanical cleaning (coagulation + filtration);
- chemical or mixed (physico-chemical) treatment;
- periodical partial replacement of water and feeding with «fresh» water.

The main tasks performed by the circulation:

- elimination of stagnant areas in the catchment area (if any) to prevent the development of organic matters (microorganisms and algae);
- active mixing of water streams and uniform distribution of disinfectant chemicals in the engineering of the facility;
- uniform distribution of pollutants and substances that ensure oxidation, coagulation and filtration processes.

Efficient water circulation in the bed of the catchment basin is achieved by moving water streams – by the selection of contaminated water to the water treatment system and return of treated water back into the technological process.

Mechanical cleaning makes it possible to clean water from insoluble impurities. Bed filters are the most effective for mechanical cleaning. To increase the efficiency of the filter and additional water clarification, it is recommended to apply coagulation as the means for removing suspended particles. The coagulants should be introduced immediately before the filters in strictly calculated quantities using programmable dosing equipment.

The chemical or physico-chemical treatment of water is carried out in order to ensure the necessary hygienic, sanitary and aesthetic requirements, and includes the following processes:
- pH adjustment;
- disinfection;
- destruction of organic matters and pathogenic microorganisms;
- coagulation of suspended particles;
- additional (specifically situational) processing.

To destroy organic matters and pathogenic microorganisms in water, the following methods are applied:
- chlorination;
- ozonation;
- ultraviolet radiation treatment;
- salt electrolysis systems;
- systems based on water ionization (copper, silver);
- chlorine-free disinfection based on hydrogen peroxide and colloidal silver;
- additional chemical additives.

The abovementioned methods are described in detail in many literature sources. However, it should be noted that none of them gives a 100% disinfection effect. The use of combined methods allows to increase the effect of water disinfection. The method of water treatment or a combination of these methods, composition and design parameters should be taken depending on the quality of water at the source, the performance of engineering of the fountain and on the basis of experience of operation of the engineering in similar conditions.

A comparative analysis of specialized publications in the field of water supply engineering systems, including publications on hydraulics and hydraulic engineering proves that the main parameters in the formation of fountains in urban spaces set:
- the shape and size of the catchment area in the layout (if any);
- orientation of the catchment area in relation to the prevailing wind direction;
- architecture of water and features of its formation (area, arrangement of static and/or dynamic movement of water streams, presence of air corridors).

The *catchment area* (Fig. 4:10) is an element of engineering of the structure and the dominant element when determining the main technical parameters in formation of the fountains in urban spaces (provided that it is not identified with a natural or artificial source), can be described as a complex of structures and technical equipment (devices), which are functionally interconnected and designed to collect and organize the circulation of water streams. It is recommended to place the technological equipment of the catchment basin together with the PS equipment. The catchment complex includes:
- catchment area bed, as the main structure of the complex, determines the type of catchment area;
- water treatment system, which ensures the quality of water used in accordance with current sanitary norms;
- PS drainage - provides water intake from the catchment area bed and return water to the technological process;
- site on the outer perimeter of the catchment area;
- external catchment system of the structure, which is designed to collect water that was carried by the wind outside the outer fence of the catchment area.

In fountains without catchment beds, the external catchment system performs the main function of the catchment bed – collection of water (destroyed water streams).

The catchment area bed shall have a shape and design size in layout, which is sufficient to create a protective zone that prevents the removal of water (drops) by wind (Fig. 6).

The protective zone (Fig. 1) is located between the zone in which the water architecture is formed and the side of the catchment bed. The higher the architecture of water, the higher the wind force with which it interacts [5,6].

In the absence of wind (V_w = 0, m/s), the destruction of the water stream occurs vertically. Under the influence of wind (V_w > 0, m/s), in the course of destruction the water streams create a «water shadow», which determines the angle of falling of drops on the water surface in the catchment bed. The higher the wind speed, the greater the water shadow, which is formed by the stream during the destruction, and the greater the angle of falling of the drops. The shape of the water shadow, the angle of falling, the distance to which water drops are carried by the wind depends on the wind speed V_w, m/s, the height of falling of drops $h_в$, m, and the characteristics of the drops. Provided that the wind pressure per drop is equal to its mass, the drop falls on a parabolic curve tangent to which is close to 45^0.

Knowing the average wind speed V_w, m/s, according to the graph given by P.A. Spyshnov [5, p.154, Fig. 150], one can determine the required characteristics of the drop, which will provide at a given wind speed collection of drops in the catchment bed. Ignoring the described process of water stream destruction results in removal of water by wind to the functional zone of interaction of the structure with the urban space. Excessive removal of water by the wind contributes to the death of vegetation, which is located at a close distance from the fountain and accelerates the destruction of the site, which is arranged along the outer perimeter of the catchment area.

Conducted studies demonstrated that the area wherein the water architecture and the size of the catchment bed are formed, are interrelated [45]. The estimated size of the bed is taken so that the destruction of water streams by wind occurs within the limits set by the side of the bed. Given the above, the estimated size of the catchment bed should be set at the maximum allowable height of the design zone $h_{в\,max}$, m, in which the water architecture is formed (Fig. 6):

$$h_{AW\,max} = 2/3\, l = l_1, \text{ mm}$$

where l, mm is the distance from the central point of the bed to the side;
and l_1, mm is the distance from the central point of the bed to the boundary of the zone wherein the water architecture is formed, is taken equal to half of the design distance in which the water architecture is formed l_{AW}, mm:

$$l_1 = ½\, l_{AW}, \text{ mm.}$$

The depth of the catchment bed h_C, mm (if it is not subject to special requirements for the creation of a water reserve) is taken 500-1000 mm, and the normal working layer h_1, mm in it is 300-700 mm. The board (inner fence) of the bed is made in the form of a vertical wall, less often in the form of gentle slopes. The slopes and the bottom of the catchment area are covered with protective clothing, which protects the surface from the erosion of falling water. The selection of type of clothing is influenced by topographic and engineering-geological conditions of the urban situation, primarily, the geological structure and physico-chemical properties of the soil [7, p.197].

Depending on the space conditions (topographic and engineering-geological) and the main functional purpose of the structure, the authors of publications in the field of water supply and hydraulic engineering recommend to arrange a site along the outer perimeter of catchment basin with a special coating, width of about 5000 mm ($l_c \approx$ 5000 mm) and slope i=0.05 from the outer fence of the catchment bed to the outer catchment system. An external catchment system is arranged along the outer perimeter of the site in order to reduce the possibility of puddles and dirt near the bed due to the removal of water by wind outside the fence, and to prevent wind contaminants from entering the bed of the catchment area. The system shall have a protective coating designed for the same parameters as the bed of the catchment, taking into account the additional load from temperature fluctuations and erosion effect of the water.

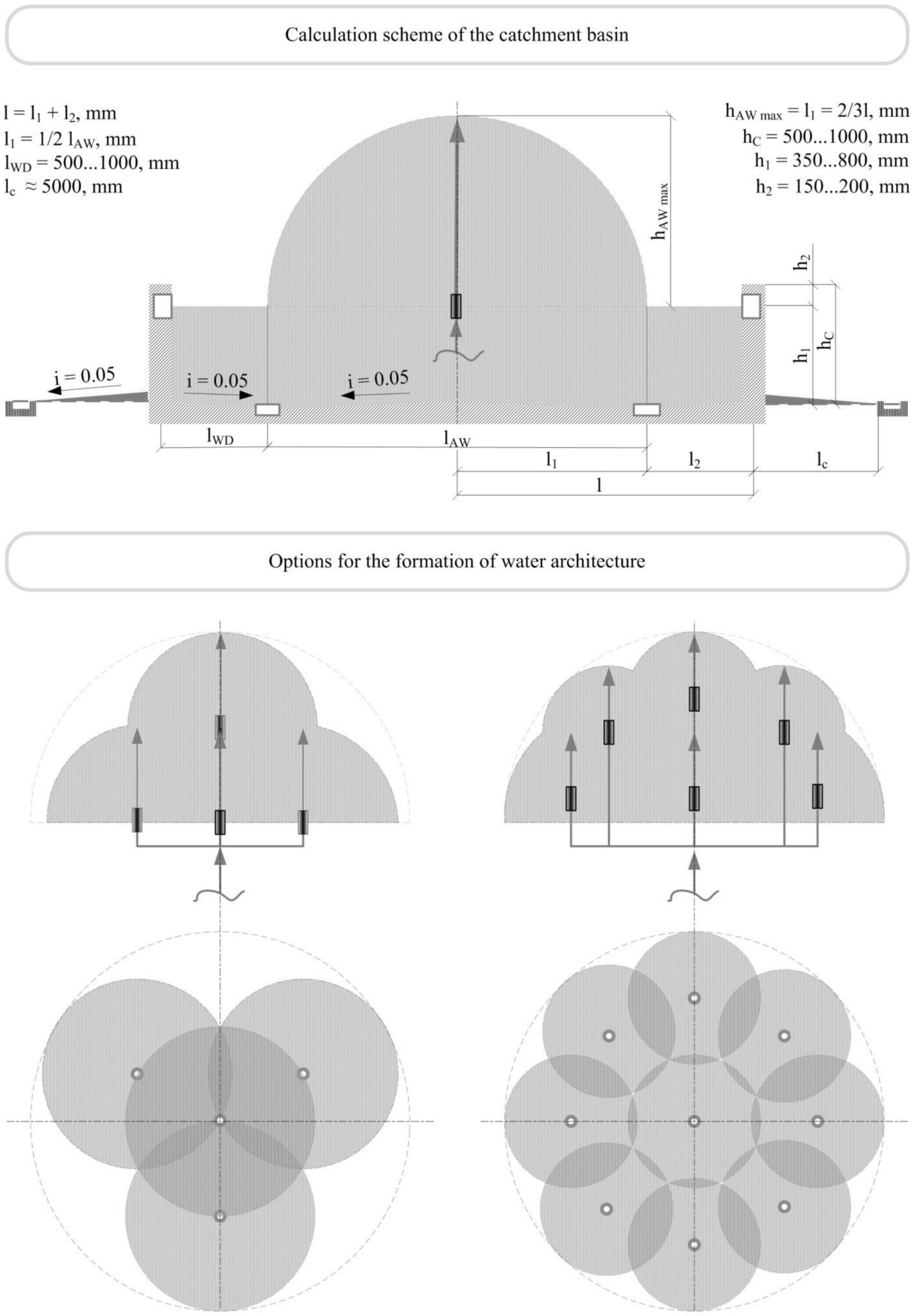


Fig. 6 Calculation scheme of the catchment basin bed with options for the formation of water architecture (illustration: O. Tserkovna)

In order to timely remove contaminants and facilitate emptying, the bottom of the bed is arranged at an angle $i = 0.05$ to the place of water collection (Fig. 6) by WD engineering system [6, p. 204].

In terms of the peculiarities of the water stream movement arrangement, the beds of catchment basins can be divided into:

- *skimmer type* (with concentrated water intake from the board and bottom of the bed) (Fig. 7 a);
- *overflow type* (with scattered overflow of water from the bed) (Fig. 7 b);
- *concentrated type*, where water is taken from the bottom of the catchment basin bed (Fig. 7 c).

In the bed of skimmer type (Fig. 7 a), the water streams are displaced into the window, which is formed on the board of the bed (Fig. 7 a: 1) - skimmer (Fig. 7 a: 4). One skimmer is designed for water intake from the water surface area S_c, which is equal to 20-40 m^2. The number of skimmers n is calculated based on the water surface area S_{AW}, m in the bed of the catchment:

$$n = S_{AW} / S_c.$$

The skimmers are installed at a depth h_s, which is equal to 150 mm from the upper edge and along the board of the bed at an equal distance (Fig. 7 a). The distance between the skimmers l_s, mm is determined by the formula:

$$l_s = P_b / n, \text{ mm}$$

where P_b, mm is the perimeter of the catchment bed.

The skimmers take about 70-90% of the total volume of water from the catchment basin bed, the rest falls on the bottom drain (Fig. 7 a: 5).

The bottom drain is installed at the bottom of the bed (Fig. 7 a: 2) at a distance $l_{д\ сл}$, which is equal to 500-1000 mm from the board, on the same line with the skimmer – such arrangement ensures uniform circulation of water streams in the basin bed (Fig. 7 a: 3). The bottom drain is also used to empty the bed for the period of decommissioning of the structure (laying-up for the cold period of the year).

In overflow basins, the water is evenly fed by the nozzles (Fig. 7 b: 7) into the bed, then overflows into another bed or into a special gutter (Fig. 7 b: 8), so called *overflow tray*. The overflow tray is arranged around the perimeter of the bed or on one side according to the engineering design, which determines the construction of the water architecture. The width of the overflow tray $l_л$, mm is assigned from 200 to 350 mm.

In basins with a concentrated intake of water from the bottom, the boards of the bed, as a rule, are placed at different levels (Fig. 7 c). The design of the bed is calculated in terms of the concentrated drop of water on a single-stage or multi-stage difference. The water is fed by the nozzles evenly to the upper level (Z^1_n), then collected in a concentrated manner from the bottom of the bed (Z^1_{n-x}).

Other options for arrangement of the water stream movement in the catchment basin beds are given in Fig. 8 (a).

Similarly, Figure 8 (b) presents the options of forms of catchment basins, which are proposed in the study by V.V. Goncharov [11, p.24]. The diagram demonstrates the distance L_w, mm, which is passed by the air stream under the influence of wind. The distance is the same for all proposed options.

But according to the research by V.V. Goncharov [11], and the research by H. Jin et al. [20], if the wind direction W changes, then for option *a* (Fig. 8 b: a) the scheme of interaction of air streams and the water surface will not change. For options *b, c,* and *d* (Fig. 8 b: b, c, d), the selected scheme of the interaction of air streams and water surface will be a special case, which is observed with a certain probability. In the form *e* (Fig. 8 b: e), there will be an incorrect formation of air corridors when creating a water architecture.

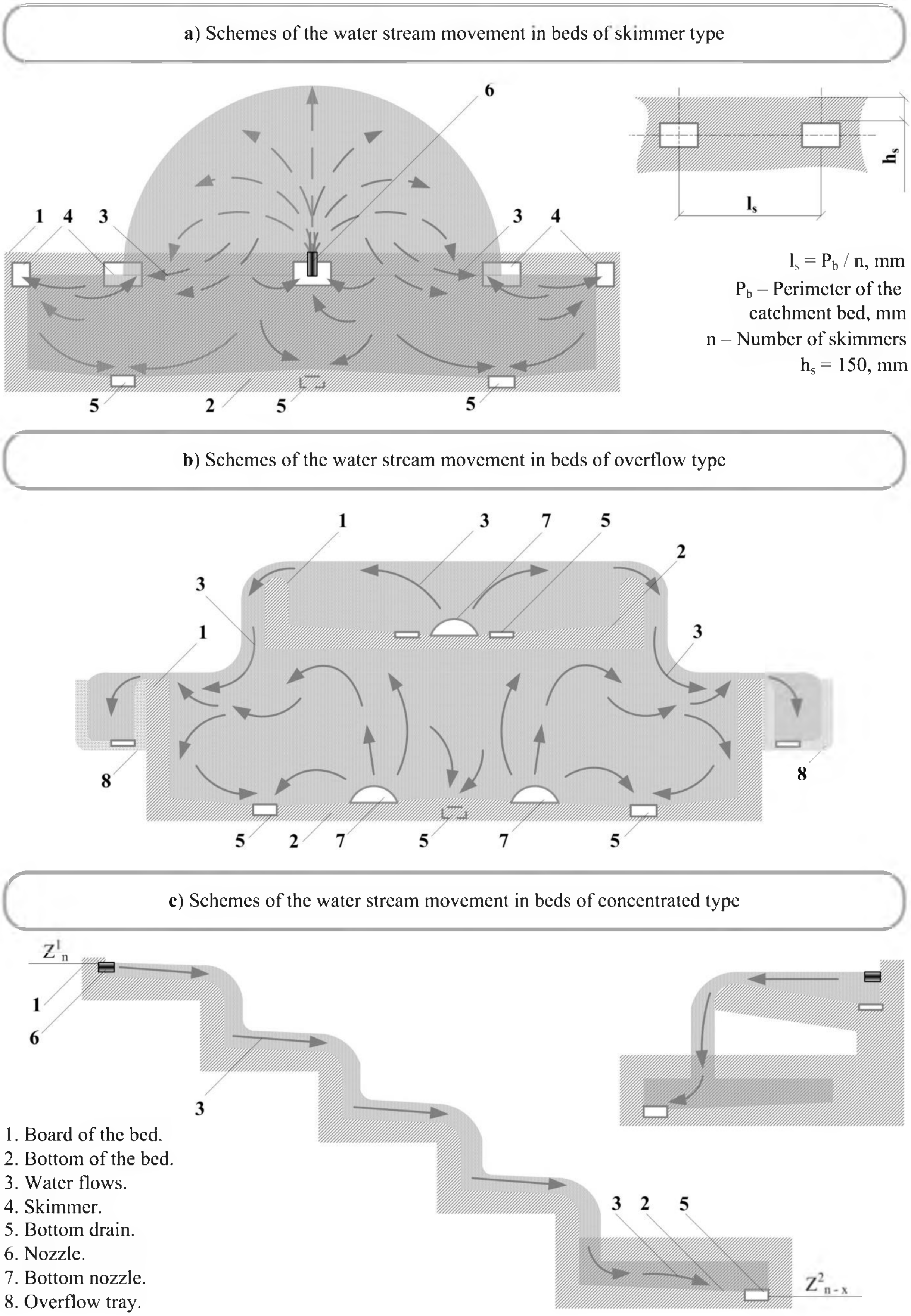
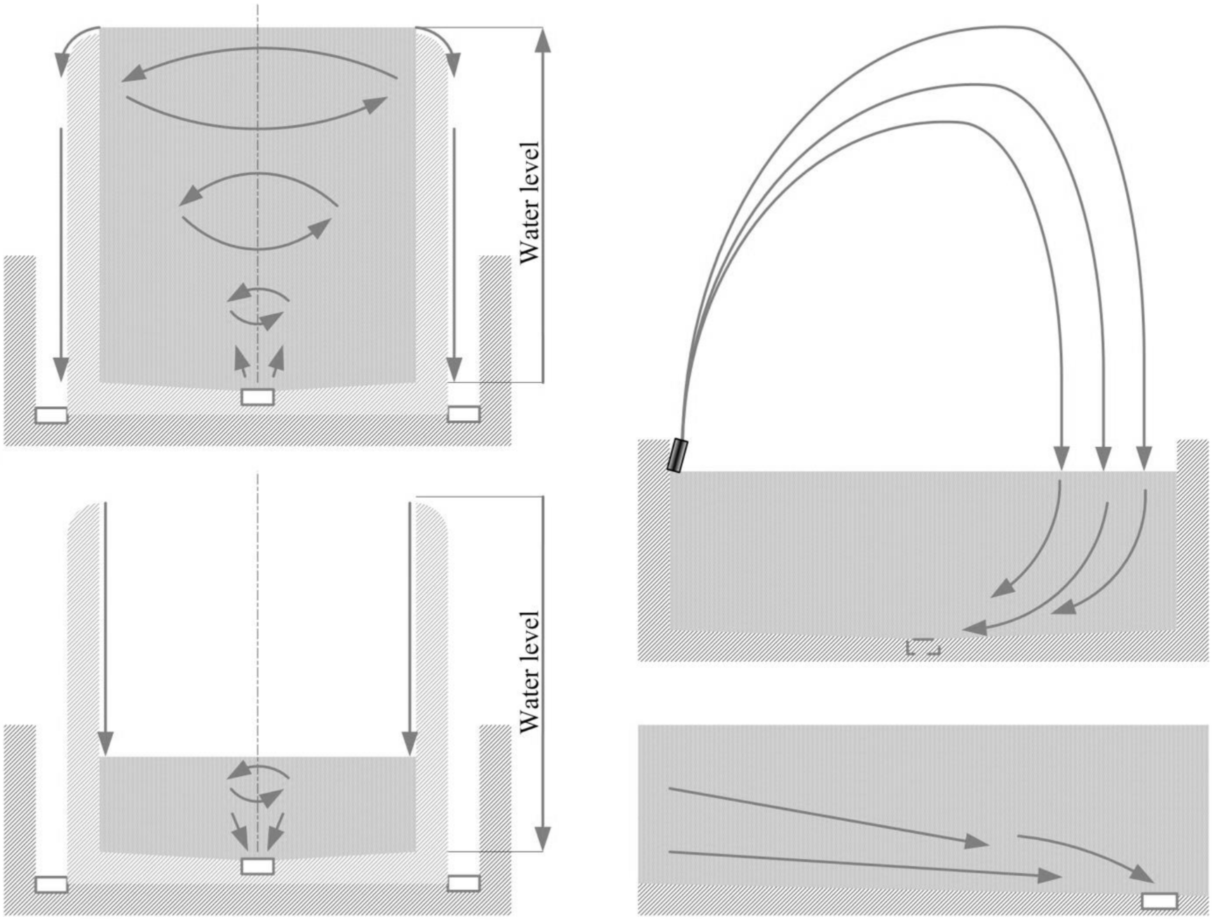


Fig. 7 Options for schemes of the water stream movement in beds of a catchment basin (illustration: O. Tserkovna)

a) Options for arrangement of the movement of water streams in beds



b) Ptions for the forms of catchment basins taking into account the wind direction ***W***

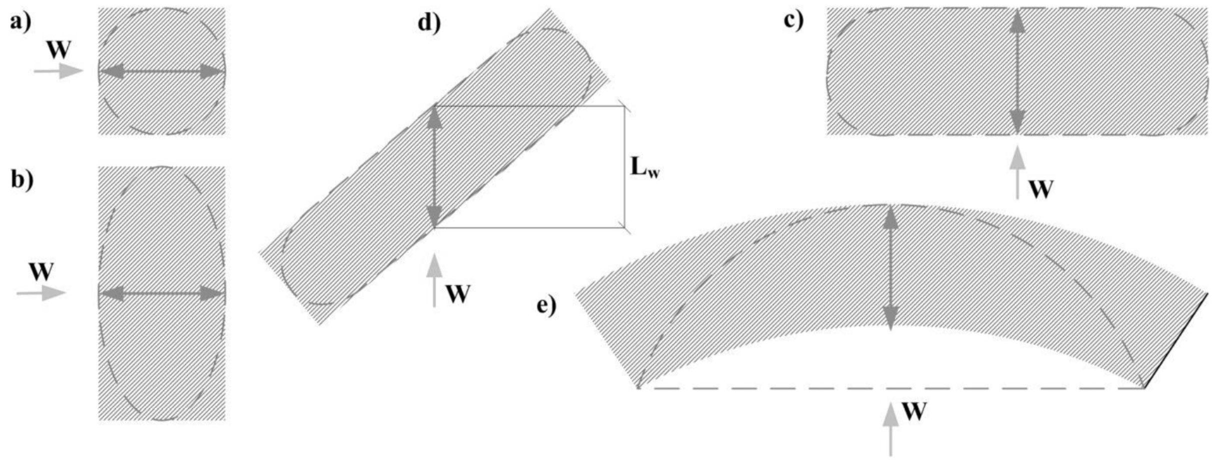


Fig. 8 Options for arrangement of the movement of water streams and options for the forms of catchment basins, which were proposed by V.V. Goncharov (illustration: O. Tserkovna)

For better interaction of air streams and water surface, the catchment basin is recommended to be located in an open area, accessible from all sides of the wind, and the main condition: the narrow side of the basin should be located in the direction of wind (Fig. 8 b), which prevails in summer. Water catchment areas of compact shape due to more favorable conditions for the flow of fresh air streams ensure a higher result when cooling and humidifying air streams. With large linear dimensions of the catchment in the layout, it is recommended to divide it into sections, creating a complex of small structures with the possibility of maintenance, repair, and if necessary, modernization of one of the sections in the operation of others. Each section of the complex of structures is equipped with its own drainage network for water drainage during washing and emptying of the bed of the catchment area for the period of decommissioning of the structure.

Mechanical change in the architecture of water (increase or decrease of its area) can be achieved with the help of nozzles (Fig. 4: 8), which create an unflooded stream (jet) [5,8,11,13]. The water is supplied to the nozzles under pressure and comes out in the form of jets, which under the influence of gravity break up into drops and collect in a bed (Fig. 4: 10) or an external catchment system (Fig. 4: 12). In relation to the bed, the nozzles are arranged: in linear, compact or disperse way, this depends on the characteristics (performance and geometric shape of the jet). The outlets of the nozzles are directed:
- horizontally or at a certain angle, with the gravitational movement of water in engineering;
- vertically upwards, at pressure gravitational movement of water in WS engineering system;
- vertically upwards or at a certain angle, at the pressure movement which will occur by inertia under the influence of the initial speed created by pressure in WS engineering system of a structure.

When water comes out of the nozzle, which is directed vertically upwards or at a certain angle, the water jet breaks up into drops. Each drop moves along the trajectory of a body thrown at an angle to the top and meets on its way the resistance of air streams. But due to the fact that the size, angles of exit and initial velocities of the individual drops are different, the trajectories of their movement also do not coincide with each other, and the water coming out of the nozzle forms a water stream filled with moving drops.

The following types of nozzles are used for mechanical change of water architecture:
- *Centrifugal* (*screw and tangential*) - the water flow under pressure is given a rotational motion by installing inside the housing of the guide apparatus with screw blades (screw nozzles).
- *Slotted* - the nozzle has a hollow body with narrow slit-like slots for water stream outlet.
- *Impact* - the holes in the nozzles are arranged in such a way that the water jets when they come out collide with each other or crash into some obstacle at the exit.

In nozzles with axial water supply, which do not have screwing devices, the spray jet angle is not very large, which is not favorable if the main task of the structure is humidification, cooling and purification of atmospheric air. In centrifugal nozzles, by changing the ratio of the basic geometric dimensions, in a wide range, it is possible to change the configuration of the water stream. For the same type of nozzles with different diameters of the outlet, the water consumption rate changes [7, p.123].

Similarly, provided that the main task of the fountain is aimed at humidification, cooling and purification of atmospheric air, it is not favorable to use nozzles that form water jets enriched with large bubbles filled with a gaseous mixture. With a high content of gases in the water, the absorption of atmospheric air actually stops [3]. Therefore, nozzles that produce foam jets (geysers) do not solve the problem of cleaning the air, but they can be applied to create water barriers or as decorative elements.

In order to limit energy consumption in PSs and reduce water consumption to be removed by the wind, L.D. Berman [7] recommends the use of nozzles that form drops of relatively large size. Fine spraying of water is complete evaporation of drops of the smallest fractions, increase in water consumption in engineering of a structure and humidification of atmospheric air above necessary parameters.

The characteristics of the nozzles of different types, their performance, the height of the water stream they form and the dispersion of the water spray must be specified in the technical data sheet provided in the package by the manufacturer.

Conclusions. Having synthesized graphic and technical languages, the author considered and described:

- The factors that dictate the organization of engineering of the structure and features of its operation. The urban planning factor consists of the components such as: resources provision for the implementation of the planned measure (source of water and power supply of the structure, the availability of sufficient space for the arrangement of the structure); topographic and engineering-geological conditions of the terrain (rise or fall of the terrain; soil types; presence of groundwater; degree of subsidence of the soil; etc.), space characteristics (climatic and acoustic). The aesthetic factor is defined as ensuring the integrated introduction of fountains into the structure of urban space.
- The importance of knowledge of the characteristics and state of atmospheric air within space when arranging the engineering of the structures (composition and concentration of pollutants, the presence of circulation) is reflected in the description of the interaction of water and air streams, impact on atmospheric air and changes in space, wind or progressive air streams, which ensure the implementation of hydrophysical processes occurring in the course of operation of the structures. The characteristics of progressive air streams, which are important in the formation of fountains in space, are defined: average speed, predominant direction, and repeatability.
- Based on knowledge of the physical and chemical properties of water, the methods are revealed that make it possible to model the temperature, humidity and noise regime of urban spaces with fountains and reduce the concentration of pollutants in the air within the space. The ability to control hydrophysical processes that occur in the course of the operation is considered through the conditions of selection of schemes for water supply engineering system and calculation of the main elements that dictate the formation of structures in space: the shape and size of the catchment basin in the layout (if any); orientation of the catchment basin in relation to the prevailing wind direction; features in the formation of water architecture (area, organization of static and/or dynamic movement of water streams, the presence of air corridors).

The main technical parameters for the formation of fountains in urban spaces are defined; there is a tool that aims to help architects, engineers and other creators of settlements for creation of the effective models of fountains, which are aesthetically and economically sound, perform scenarios conditioned by the city-planning situation, where the basic concept is aimed at improving the space. In addition, certain basic technical parameters are defined which will be used to improve the typology of fountains. They will be the basis on which graphic models and techniques of architectural and planning organization of urban spaces with fountains are developed, which, being perfectly integrated into the urban contexture, will solve environmental, economic and social urban planning problems, providing aspects of sustainable development of the urban spaces with fountains over time.

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ВИЗНАЧЕННЯ ОСНОВНИХ ТЕХНІЧНИХ ПАРАМЕТРІВ ПРИ ФОРМУВАННІ ФОНТАНІВ У МІСЬКИХ ПРОСТОРАХ

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Анотація. У статті висвітлюється проблема втрати архітекторами навичок і знання поєднувати параметри міських просторів з ефективними моделями фонтанів, які обґрунтовані естетично та економічно, виконують обумовлені містобудівною ситуацією сценарії, де основна концепція спрямована на оздоровлення простору. Базуючись на спеціалізованих виданнях в області інженерних систем водопостачання, включаючи видання з гідравліки та гідротехніки, розглянуті у комплексі фізичні та хімічні можливості води як методи, що дозволяють її комплексне використання для поглинання і транспортування із атмосферного повітря механічних та розчинених домішок, охолодження повітряних потоків. Фонтан висвітлюється як об'єкт містобудівного проектування, а вода та її рух - як основний елемент, що дозволяє керувати гідрофізичними процесами, які протікають у просторі та часі, в період експлуатації споруд і спрямовані на оздоровлення простору. Рух води - забезпечує інженерія фонтана. Автором виділені фактори, які диктують формування інженерії у просторі: ресурсне забезпечення; топографічні та інженерно-геологічні умови; кліматичні та акустичні характеристики. Розглянуто, яким чином інженерія фонтанів в період експлуатації забезпечує взаємодію повітряних і водних потоків. Детально описано: схеми інженерних систем водопостачання та водовідведення споруд; особливість експлуатації; розрахунок основних елементів, які диктують формування споруд у просторах. Визначені основні технічні параметри при формуванні фонтанів у міських просторах - є інструмент, що допоможе при створенні ефективних моделей фонтанів і при забезпеченні сталого розвитку просторів у часі.

Ключові слова: фонтани, міські простори, керування гідрофізичними процесами, формування інженерії, розрахунок елементів, визначення параметрів.

ОПРЕДЕЛЕНИЕ ОСНОВНЫХ ТЕХНИЧЕСКИХ ПАРАМЕТРОВ ПРИ ФОРМИРОВАНИИ ФОНТАНОВ В ГОРОДСКИХ ПРОСТРАНСТВАХ

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Аннотация. В статье освещается проблема потери архитекторами навыков и знаний сочетать параметры городских пространств с эффективными моделями фонтанов, которые обоснованы эстетически и экономически, выполняют обусловленные градостроительной ситуацией сценарии, где основная концепция направлена на оздоровление пространства. Основываясь на специализированных изданиях в области инженерных систем водоснабжения, включая издание по гидравлике и гидротехнике, рассмотрены в комплексе физические и химические возможности воды как методы, которые позволяют ее комплексное использование для поглощения и транспортировки из атмосферного воздуха механических и растворенных примесей, охлаждение воздушных потоков. Фонтан освещается как объект градостроительного проектирования, а вода и ее движение - как основной элемент, позволяющий управлять гидрофизическими процессами, которые протекают в пространстве и времени, в период эксплуатации сооружений и направлены на оздоровление пространства. Движение воды - обеспечивает инженерия фонтана. Автором выделены факторы, которые диктуют формирования инженерии в пространстве: ресурсное обеспечение; топографические и инженерно-геологические условия; климатические и акустические характеристики. Рассмотрено, каким образом инженерия фонтанов в период эксплуатации обеспечивает взаимодействие воздушных и водных потоков. Подробно описано: схемы инженерных систем водоснабжения и водоотведения сооружений; особенность эксплуатации; расчет основных элементов, которые диктуют формирование сооружений в пространствах. Определенные основные технические параметры при формировании фонтанов в городском пространстве - инструмент, который поможет при создании эффективных моделей фонтанов и при обеспечении устойчивого развития пространств во времени.

Ключевые слова: фонтаны, городские пространства, управление гидрофизическими процессами, формирование инженерии, расчет элементов, определение параметров.