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INNOVATIVE MEANS OF NORMALIZING PHYSICAL FACTORS THE ENVIRONMENT IN THE PROCESSES OF RECONSTRUCTION AND RESTORATION HISTORICAL HERITAGE OBJECTS

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Abstract

The problems of reconstruction and restoration of historical buildings and structures are relevant all over the world. It is especially important for Ukraine, where a large number of historical buildings and buildings of architectural value have been destroyed or damaged by military operations. The developed composite materials allow, due to their small thickness, to reduce the levels of electromagnetic fields and noise to values that meet modern international standards. A particularly important result is the reduction of low-frequency noise levels (by 12–30dB), which is practically not absorbed by building materials and structures. LED sources-ultraviolet radiation can be used in the presence of people for at least 8 hours without reaching the maximum permissible exposure level of 30J/m^2 according to SBM-2015. The use of LED ultraviolet radiation sources allows to increase the concentration of ions in deionized air to the standard concentration (500 cm^{-3}) within 10 minutes according to SBM-2015 and disinfect the environment.

***Keywords**: Historical building; Reconstruction; Electromagnetic field; Noise; Air ionization*

Introduction

The problems of reconstruction and restoration of buildings and structures are relevant all over the world. It is especially important for Ukraine, where a large number of historical buildings and buildings of architectural value have been destroyed or damaged by military operations. The specificity of their reconstruction or restoration is a need to preserve the external appearance and internal interiors. Therefore, all means of normalizing physical factors in the premises of such buildings should be invisible and not distort the interiors. An important aspect of works on the restoration of historical heritage sites is research on the compatibility of the latest building and facing materials with old concrete, brick, etc. At the same time, the thickness and weight of the materials used in the process of work should be minimized. The revitalization of buildings has certain features [1, 2]. Brick and concrete structures require different transitions to shielding noise and electromagnetic fields: concrete structures have reinforcement that can shield electromagnetic fields but have low noise reduction indices. Also, interventions in the construction of buildings, the use of modern building materials and the use

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of the latest engineering networks must comply with legal principles [3]. That is, certain preparations must be made to rebuild destroyed or damaged historic buildings [4]. From the point of view of ensuring that such buildings comply with the normative values of electromagnetic fields, noise and air ionization, it is necessary to determine the necessary and sufficient level of interference with the building structure. One of the directions of such work is to minimize the weight and size parameters of protective materials and structures and their invisibility. The most critical physical factors that can negatively affect people's health are electromagnetic fields (EMF), noise and non-normal air quality. At the same time, concentrations of light air ions of both signs have the greatest impact on air quality, which is due not only to the negative impact of deionized air on people, but also to the interaction of ions with fine dust and aerosols. Quantitative values of EMF in premises and rooms, noise and ion concentration are regulated by the European standard SBM-2015 [5].

A lot of attention is paid to the problem of normalizing the levels of these physical factors in the premises. The most effective method of EMF reducing is their shielding with protective composite materials. Most of such materials are intended for shielding the EMF of ultra-high and higher frequencies [6, 7]. The main disadvantages of such materials are relatively large thickness, which does not allow covering surfaces of complex configuration. In addition, they have complex manufacturing technologies, are prone to degradation during operation and have a high cost [8]. There is an actual need to shield EMFs of industrial frequency. But the existing materials have a lattice structure and are inconvenient for use inside buildings [9]. Compositions on a synthetic basis are more acceptable [10]. But they are multi-component, have a complex manufacturing technology, high cost and inconvenience for application on large area surfaces. Therefore, it is advisable to investigate the possibility of manufacturing a liquid composition made of cheap components with acceptable efficiency in a wide EMF frequency range. In order to ensure the necessary shielding coefficients of EMFs, taking into account the provision of sufficient mobile communication signals, it is necessary to develop many experimental samples. This procedure can be simplified using field propagation modeling [11]. Taking into account the value of the spatial harmonics of the magnetic field in the model minimizes calculation errors compared to the experiment. Most of the studies on reducing the impact of noise on people relate to traffic noise - automobile and aviation [12]. Therefore, most structures for reducing noise levels are external noise-absorbing perforated structures. In historical buildings and buildings of old construction, sound insulation is not foreseen and it is impossible to apply traditional noise-absorbing material on external and internal surfaces. It is advisable to develop a noise-absorbing composite material of small thickness with acceptable noise reduction indices. This especially applies to low-frequency noise that is not absorbed by brick structures. It is possible to predetermine the design features of protective materials and sound propagation modeling panels [13]. To quickly choose a design with the required efficiency, it is advisable to automate the process. An important environmental problem in historic buildings is air quality. This is due to the lack of modern ventilation systems, which leads to air deionization and the development of colonies of pathogenic bacteria and fungi. For such rooms, it is advisable to use artificial air ionization. But existing approaches to solving this problem consist in the use of high-voltage and ultrasonic air ionizers [14]. This method requires the separation of ions from the source by directed air movement, which is not always possible and advisable. The presence of furniture and different technical equipment in the premises makes the ion concentration distributions of both signs unpredictable [15]. Determining the distribution of air ions in rooms with the provision of regulatory concentrations can be a difficult task. So, it is necessary to model the distribution of air ions from the source in the presence of obstacles to the air flow [16]. The paper [17] shows the possibility of debacterizing indoor air using low-intensive ultraviolet radiation. Therefore, it is advisable to investigate the effectiveness of using this method to improve the air environment in buildings with ventilation systems of low efficiency. Such systems will not change the internal structure and interiors of reconstructed and restored buildings. Thus, the task of a complex of measures aimed at normalizing the levels of physical factors in reconstructed and restored buildings and structures is urgent.

Materials and methods

The materials for shielding EMFs of a wide frequency range were manufactured using environmentally friendly geopolymer paint (matrix). Refractory inorganic geopolymers are resistant to aggressive environments, have high adhesion to building materials, in particular to concrete structures. They meet the requirements of the EN1504 standard. Chemically neutral magnetite and flake graphite in various concentrations were used as shielding filler. The advantages of magnetite are sufficient relative magnetic permeability (4.2–4.6) and electrical conductivity (up to 1000 S/m). Magnetite is the main component of iron ore concentrate (up to 98%), which is produced in large quantities by mining enterprises. It has high dispersion (average particle size is 20–22 microns). This allows to obtain a uniform distribution of particles in the matrix. The advantages of flake graphite are high relative dielectric constants (12–15) and electrical conductivity (up to 1400 S/m). The scaly structure of graphite contributes to the formation of circles electrical conductivity, which increases the shielding coefficients of electromagnetic fields. It is produced in large quantities for the needs of metallurgy. Barium sulfate with a dispersion of 10–12 microns contributes to the uniform distribution of fillers in the material and increases the effectiveness of shielding high-frequency radiation. For the manufacture of the noise protection coating, environmentally friendly latex was used in the form of a small thickness foam latex (foaming agent 2–3% by weight). Fine polystyrene foam was added to the matrix to increase the noise reduction coefficients. The ionization and debacterization of the indoor air was carried out using ultraviolet radiation LEDs with a predominant wavelength of 280 nm of the LED UVC T-5W-275 NM brand. The value of the UVC exposure dose for 8 hours at a distance of 2m from people (under the ceiling) did not exceed the maximum permissible value for people (30 J/m^2 according to SBM-2015). Measurements of the shielding coefficients of ultrahigh frequency EMFs were carried out by a calibrated device P3-31 using a special stand with a hole that excluded the penetration of radiation outside the screen due to diffraction phenomena. Measurement of the shielding coefficients of the EMF of industrial frequency 50Hz was carried out using a closed cubic shield. The measuring antenna of the P3-50 device was placed inside the shielding structure with the cable leading to the device through a technological hole. This excluded the penetration of the shielded field to the measuring antenna outside the screen. Changes in the ion concentration were carried out by the MAC-01 air ion counter. The number of mold colony forming units and total microbial counts were determined using R-Biopharm AG (Germany) test systems. The levels of ultraviolet radiation were monitored during the study by the Argus 06 device. LED ultraviolet emitters were connected to the standard lighting systems in the room and were invisible to the eye. During the research, the test rooms maintained the standard values of microclimate, natural and artificial lighting in accordance with SBM-2015.

The aim of the study is to develop composite materials with small weight and size parameters for shielding electromagnetic and acoustic fields; as well as air ionization and debacterization means suitable for use in the process of restoration and reconstruction of historical architectural and urban buildings and structures.

Results and Discussions

According to the Ministry of Culture and Information Policy, only between February 24, 2022 and December 25, 2023, 872 buildings or structures of cultural heritage were damaged or destroyed as a result of the armed aggression of the Russian Federation in Ukraine. By July

2024, this number will exceed 2,000. However, this value is not final. A significant part of the damaged objects of cultural heritage is located in the temporarily occupied territory. Among them are objects of architecture, urban planning, history etc. These buildings and structures were constructed at different times, using different structural and technological approaches and from different materials. In the process of reconstructing historic buildings and structures, it is necessary to comply with modern requirements for the state of the internal environment: levels of electromagnetic fields, noise, low-frequency sound, infrasound, air quality in terms of air ions and dangerous microflora. This puts forward special conditions for protective materials and means of improving the indoor environment in buildings undergoing renovation.

Buildings for religious purposes are characterized by complex relief on internal and external surfaces (Figs. 1 and 2).

Fig. 1. Destruction of the main cathedral of the Eparchy of Odesa founded in 1795.

Fig. 2. Damage to the house of Peruvian merchants in Kherson after Russian shelling, built in 1905 in Kherson

In the process of restoring the interior and exterior surfaces of such structures, all materials used to protect against harmful effects must have a minimum thickness that is invisible when viewed. Liquid finishing protective materials and LED ultraviolet radiation systems can provide this effect.

Many historic buildings have damaged roofs and windows (Figs 3-5).

Fig. 3. Damage to a historical monument, the former Chernihiv District Court building, built in 1904.

Fig. 4. The burned Koenig manor in Trostianets, built in 1726.

As a rule, such buildings are not equipped with ventilation systems, so when restoring roofs and windows made of modern materials, air infiltration is disrupted. Therefore, modern systems for improving the internal environment should be used in such buildings. In many cases, highways with high traffic intensity pass by such buildings, which are a source of not only noise but also low-frequency sound and infrasound, which are not screened by building materials. A significant number of historic buildings require almost complete restoration (Figs. 6 and 7).

Fig. 5. The building of the former Realschule in Izyum, opened 1882.

Fig. 6. Vasyl Tarnovsky Museum of Ukrainian Antiquities, Chernihiv, founded in 1896.

In the process of complete restoration of such buildings, it is advisable to apply the full range of modern means and measures of protection against the effects of physical factors. The main condition for their use should be invisibility during inspection. For this purpose, liquid finishing materials have been developed to protect against the effects of electromagnetic fields of a wide frequency range, metal-polymer materials for noise protection and innovative air ionization and debacterization systems.

Fig.7. Grigory Skovoroda Museum in the village of Skovorodynivka, Kharkiv region, located in the house of the Kovalivsky landowners, built in the XVIII century. Photo: Kharkiv Regional State Administration

The protective properties of liquid composite materials were studied. Magnetite was added to the geopolymer paint in amounts of 15, 30, 45% by weight. Samples were also made with an additional content of flake graphite and barium sulfate. The shielding coefficient is the ratio of the field strength or flux density of electromagnetic radiation in front of the protective shield to the indicator in the protected area. The results of shielding the industrial frequency magnetic field are shown in Table 1.

Table 1. Shielding coefficients of the magnetic component of the EMF of industrial frequency

No	Sample of material	K_S		
		15%	**30%**	**45%**
1	Geopolymer paint, magnetite	1,5–1,6	2,0–2,1	7,6–7,7
2	Geopolymer paint, magnetite, 5% graphite	1,6–1,7	2,1–2,2	7,5–7,6
3	Geopolymer paint, magnetite, barium sulfate 5%	1,9–2,0	2,5–2,6	7,8–7,9

The induction of the unshielded magnetic field was 280 μT. As can be seen from Table 1, graphite does not affect the protective properties of the material against the magnetic field and barium sulfate slightly increases them. This is due to the fact that the shielding of the magnetic field occurs due to the ferromagnetic material, which is magnetite.

The measured shielding values of the electric component of the industrial frequency electromagnetic field are shown in Table 2.

Table 2. Shielding coefficients of the electric component of the EMF of industrial frequency

No	Sample of material	K_S		
		15%	**30%**	**45%**
1	Geopolymer paint, magnetite	1,1–1,2	1,7–1,8	3,0–3,1
2	Geopolymer paint, magnetite, 5% graphite	2,7–2,8	3,0–3,1	8,2–8,3
3	Geopolymer paint, magnetite, barium sulfate 5%	2,8–2,9	3,3–3,4	8,9–9,0

The unshielded field intensity was 180V/m. As can be seen from Table 2, the highest shielding coefficients are inherent in samples containing graphite. Its high conductivity ensures the results obtained.

Also, the measured shielding coefficients of the electromagnetic field of ultra-high frequencies are shown in Table 3.

Table 3. Shielding coefficients of the EMF of ultra-high frequencies

No	Sample of material	K_S		
		15%	**30%**	**45%**
1	Geopolymer paint, magnetite	1,3–1,4	1,6–1,7	5,5–5,6
2	Geopolymer paint, magnetite, 5% graphite	2,0–2,1	3,1–3,2	6,0–6,1
3	Geopolymer paint, magnetite, barium sulfate 5%	2,3–3,3	3,4–3,5	6,7–6,8

The energy flux density of unshielded radiation was 180–185μW/cm^2, frequency 2,45GHz.

Samples with higher conductivity (2, 3) showed the best results. To protect against high-frequency radiation, the reflection coefficient of electromagnetic waves is important. Its high values contribute to the redistribution of radiation, which can lead to high levels of electromagnetic fields in undesirable places (Table 4).

Table 4. Reflection coefficients of electromagnetic waves by composite materials

No	Sample of material	K_r		
		15%	**30%**	**45%**
1	Geopolymer paint, magnetite	0,09–0,10	0,10–0,12	0,22–0,23
2	Geopolymer paint, magnetite, 5% graphite	0,18–0,19	0,23–0,24	0,31–0,33
3	Geopolymer paint, magnetite, barium sulfate 5%	0,19–0,22	0,25–0,26	0,37–0,38

As can be seen from the data in Table 4, the reflection coefficients increase with an increase in the concentration of the screening filler. This is due to an increase in the conductivity of the compositions.

The reflection coefficients at 45% screening material content are quite high, but the overall screening coefficients are relatively low. Increasing the content of screening filler is undesirable for several reasons.

First, with a filler content of 60%, it acquires the qualities of a putty, which is inconvenient for practical use. Secondly, there are problems with the adhesion of the material to the application surface, at least on brick and plaster. And mixtures with a filler content of up to 45% have high adsorption properties. In this case, one layer of the coating after drying has a thickness of up to 150μm.

As can be seen from the above results, an increase in the overall shielding coefficient leads to an increase in the reflection coefficient of electromagnetic waves. From the fundamental relations of electrodynamics of continuous media, it is known that the reflective properties of a material are determined solely by the electrophysical characteristics of the surface layer. In order to ensure high shielding coefficients and minimize reflection coefficients, it is advisable to apply several layers of the composition with different concentrations of the shielding material to the surface. The results of the study of two-layer coatings are shown in Table 5.

Table 5. Values of total shielding coefficients and reflection coefficients of ultra-high frequency electromagnetic waves for two-layer coatings

Sample of material	K_S	K_r
No 1 (15%) + No 2 (45%)	7,2–7,3	0,11–0,12
No 2 (15%) + No 2 (45%)	8,5–8,6	0,20–0,21
No 3 (15%) + No 3 (45%)	10,3–10,4	0,21–0,22

Table 5 shows that it is possible to ensure low electromagnetic wave reflection coefficients while obtaining high protective properties.

The challenge of creating noise-absorbing materials and structures for use in historic buildings is to minimize the thickness of the protective layer with sufficient noise reduction indices. Latex-based materials meet these requirements. During the latex production process, a foaming agent was added to the initial mixture in the amount of 2–3% by weight. It is a foaming agent that makes the polymer structure heterogeneous. Finely granular polystyrene was also added to the mixture. The samples were made with a thickness of 5 mm.

The noise protection properties of the two types of materials were tested in a reverberation chamber using stationary Brühl and Kier equipment. The test methodology complied with ISO 10140-4:2021 and ISO 354:2007.

Figure 8 shows the spectrum of noise reduction indices in the entire sound range for samples of foam latex and foam latex with granular polystyrene foam.

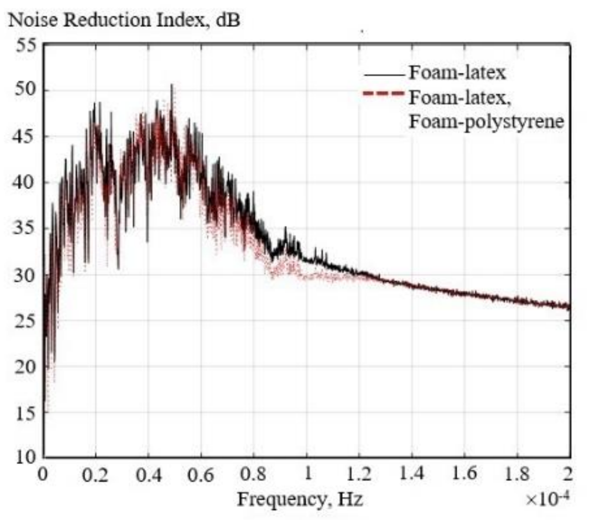

Fig. 8. Spectrum of noise reduction indices of research materials in the sound range

Such data is inconvenient to use in practical work on the design of protective material. Therefore, tests were conducted in octave bands of the sound range (Fig. 9).

As can be seen from the data in figure 9, the material with granular polystyrene foam has greater efficiency in the low-frequency part of the spectrum (noise reduction index from 12dB to 30dB). At the same time, the prototype with expanded polystyrene was 5mm thick and the one made of pure foam latex was 10mm thick. Given the complexity of screening low-frequency sound and infrasound, this result is satisfactory. At the same time, the highest noise reduction indices fall at frequencies of 2–8kHz, to which human hearing organs are most sensitive.

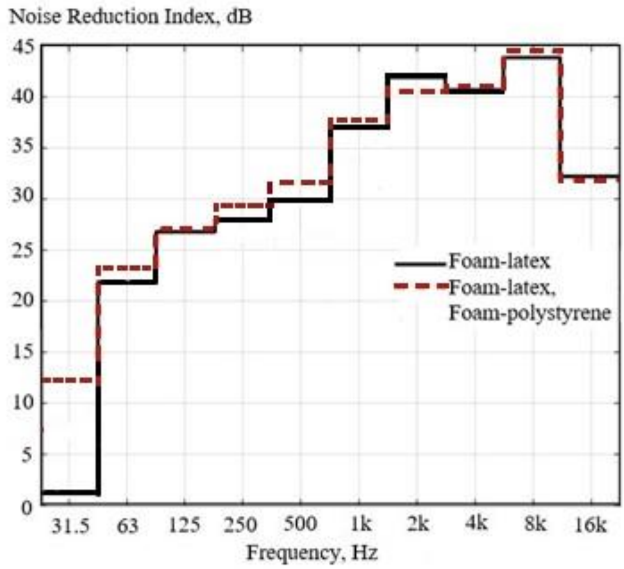

Fig. 9. Noise reduction indices of prototypes in octave frequency bands of the sound range

The possibility of simultaneous shielding of acoustic and electromagnetic fields by the composite material was investigated. For this purpose, magnetite was added to the latex in amounts of 5 and 10% by weight. A high-speed dissolver was used for uniform mixing. After that, granular polystyrene foam was added to the mixture. The results of the tests of the shielding efficiency of the electromagnetic field with a frequency of 2,45GHz and the magnetic field with a frequency of 50Hz of samples with a magnetite content of 5 and 10% by weight ρ are shown in Table 6.

Table 6. Dependence of the shielding coefficients of the electromagnetic field of industrial and ultra-high frequencies on the magnetite content

ρ, (%)	K_S	
	2,45GHz	**50Hz**
5	3,4-3,6	2,8-3,0
10	6,8-7,0	7,6-7,9

Given the low electrical conductivity of magnetite and its low content in the composite, the result is satisfactory. The reason for the high shielding coefficients is the distribution of magnetite particles in the material. In the process of mixing the mixture, they settle mainly on inhomogeneities (polystyrene granules), which creates a large number of interfaces in the material. The advantage of the resulting material is its low reflection coefficients of electromagnetic waves. For a material with a magnetite content of 5%, this figure was 0,09–0,12, depending on the angle of incidence of electromagnetic waves and for a material with a magnetite content of 10%, it was 0.16–0.19. Such reflection coefficients are practically the lowest possible given the high coefficients of total shielding, which are given in Table 6.

Changes in the concentration of ions in indoor air under the influence of ultraviolet radiation were studied. Measurements were made in three premises of equal area and volume. Two of them were equipped with LED ultraviolet radiation systems (under the ceiling, at a height of 3,3m) with a capacity of 25W. The third premise was a control room. Measurements of air ion concentrations were carried out sequentially in three premises before turning on the ultraviolet lamps. After switching on the lamps, the concentrations of air ions were measured after the onset of dynamic equilibrium of concentrations. The results are shown in Table 7.

Table 7. Concentrations of air ions in premises with the use of LED ultraviolet radiation systems

Premises	Concentrations of air ions, cm^{-3}	
	n^+	n^-
Control	150-160	160-180
UVC	1100-1200	1300-1400
UVC	1350-1450	145-1550

The time during which the concentrations of air ions reach a state of dynamic equilibrium within the measurement error of the air ion meter, was determined (Fig. 10).

The data shown in figure 10 indicate that the permissible concentrations of air ions of both polarities under the influence of ultraviolet radiation ($500 cm^{-3}$ according to SBM-2015) are achieved within 10 minutes. Such dynamics of air ion concentrations under conditions of artificial air ionization is very important for premises where it is necessary to quickly normalize the state of the environment and maintain it at a standard level for any time.

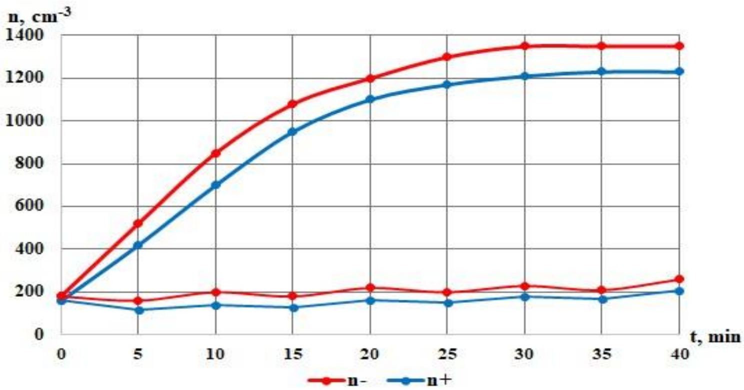

Fig. 10. Dependence of concentrations of air ions of both polarities on the operating time of LED ultraviolet radiation systems (lower curves – indicators of control displacement)

A study was conducted on the effect of LED ultraviolet radiation systems on harmful and dangerous microflora.

Quantification of microflora was assessed by the number of colonies forming units (CFU) per 1.0 dm^2 of surface of furniture, equipment etc. The swabbing method was used for this purpose.

The number of molds forming units in the premise with LED UV radiation systems and in the control, premise is shown in Table 8.

Table 8. The number of colonies of mold forming units on surfaces in the premise with the use of ultraviolet radiation and in the control premise*

Research time	UVC premise			Control premise		
	1	2	3	1	2	3
Initial data	27	7	9	25	45	36
Data after three months	7	6	6	18	44	27
Efficiency	Reduction of CFU by 2,3 times			No changes within the calculation error		

*The LED illuminators were switched on during the working day. The designations 1, 2, 3 in the table correspond to three different sampling points in the premises.

Table 9 shows the results of changes in the total microbial count in the studied premises.

Table 9. Changes in the total microbial count in the studied premises under the influence of ultraviolet radiation

Research time	UVC premise			Control premise		
	1	2	3	1	2	3
Initial data	66	70	114	33	27	36
Data after three months	23	16	52	40	27	38
Efficiency	Reduction of CFU by 2,8 times			No changes within the calculation error		

The data in Table 9 show that under the influence of LED ultraviolet radiation systems, there is a significant reduction in the number of units of dangerous microflora. This contributes to the overall improvement of the environment in buildings.

The studies show that the developed materials and devices meet the requirements for normalizing the quantitative values of physical factors of man-made origin in reconstructed historical and restored old buildings. In addition, the ultraviolet radiation of LEDs destroys pathogenic microflora, the presence of which is typical for buildings with long service lives.

The use of liquid mixtures for shielding EMFs of a wide frequency range in historical buildings has the advantage that they can be applied to surfaces of any configuration without distorting the appearance of facades and interior interiors. The thickness of the layer of the developed liquid protective coating is up to 150 microns, which is less than the thickness of standard facing materials. Therefore, they will not affect the configuration of surfaces during the restoration work. The use of such mixtures allows for the required level of EMF reduction while maintaining the stability of mobile communications. The combination of high electromagnetic energy absorption coefficients and low electromagnetic wave reflection coefficients in a multilayer material guarantees the impossibility of a sharp increase in the levels of high-frequency radiation due to their redistribution due to the reflection of electromagnetic waves. The disadvantage of such mixtures is their black color due to the presence of magnetite and graphite, or gray with the addition of barium sulfate. That is, they require an external decorative finish.

The use of foam latex and expanded polystyrene to reduce noise levels allows for high noise indices. The advantage of such materials is their sufficient efficiency in the low-frequency region of the sound spectrum, which is usually a difficult engineering task due to the low absorption of low-frequency sound by building materials and structures. The disadvantages of the developed materials are the need to produce and install separate blocks (plates) and the possibility of applying only to flat surfaces and surfaces of low curvature. It is advisable to place such sound-proofing structures in the middle of wall elements or on the inner surfaces of capital walls. In this case, the entire internal volume of the building is protected against noise. The design of protective panels should be carried out after analyzing the structural features of a specific building and studying the relevant documentation. The use of such panels is advisable after monitoring the levels of acoustic fields, which will optimize the thickness of noise-absorbing blocks and simplify their installation on the wall surface.

The use of LED ultraviolet radiation lamps for ionization of indoor air has proven their effectiveness in normalizing and maintaining the concentration of air ions of both polarities at the standard level. The advantage of this method is a quick effect – the concentrations of air ions reach the standard values (500 cm^{-3}) within 10 minutes and dynamic equilibrium – within 25 – 30 minutes. The total power of the five lamps was 25W and the volume of the premises was 110 – 120m^3. Therefore, it can be assumed that the specific UVC power of 0,25W/m^3 is quite sufficient to maintain the concentrations of air ions of both signs at levels above the minimum permissible levels, even in deionized air. Ultraviolet LEDs have an opening angle of 120°, which determines the radiation patterns. Therefore, to ensure an even distribution of air ion concentrations, the placement of ceiling-mounted luminaires should be such that the UV radiation patterns intersect at least at the level of the surfaces of indoor furniture and other equipment. Experiments have shown that under the influence of LED ultraviolet radiation, the number of colonies of molds and bacteria is significantly reduced. Given this fact, it can be concluded that there is an effect of improving the environment of buildings. All historical heritage sites are not standard structures. Therefore, in the process of their reconstruction and restoration, it is necessary to carry out certain research works in each individual case. But such works, at least with regard to determining the list of factors that need to be normalized, protective materials and the sufficiency of their effectiveness, should be carried out in a certain sequence.

At the first stage, it is necessary to study the experience of performing such works, in particular conservation practices and principles of urban logistics [18]. At the second stage, it is necessary to analyze all available documentation and photo materials regarding the object of reconstruction and restoration [19.] This will allow to minimize the expenditure of time and money on choosing means to ensure the normalization of the levels of factors of adverse impact on people. At the third stage, it is necessary to determine the list and properties of building and facing materials from the point of view of their resistance to external influences and interaction with old building materials [20].

Developed materials for reducing the levels of electromagnetic fields and noise have controllable protective properties due to the content of fillers in the thickness of the number of layers. Implementation of preparatory work in the given sequence will allow choosing the most rational indicators of protection means.

The use of developed materials and devices for normalizing the levels of physical factors and improving the environment make it possible to achieve indicators in historical buildings that meet the requirements of modern international standards and sanitary norms.

The conducted research has a perspective. The environment of modern cities has significant infrasound pollution generated by traffic flows and other infrastructure facilities. Infrasound waves have low attenuation coefficients in airspace and are practically not absorbed by building materials and structures. Infrasound can be absorbed only by resonant structures such as Bekeshi panels. It is advisable to investigate the possibility of developing one- and two-layer panels made of modern construction materials tuned to resonant frequencies with the highest amplitudes of the infrasound spectrum. This requires a set of studies, which include determining typical infrasound spectra generated by the most critical sources, identifying the frequencies with the largest amplitudes and developing protective panels with minimal weight and dimensions.

Conclusions

It is proved that normalization of electromagnetic fields, noise and air ion concentrations in reconstructed historic buildings and restored old buildings is possible without changing or distorting the facades and interior interiors of buildings.

The use of innovative liquid mixtures based on environmentally friendly paints, magnetite, graphite and barium sulfate allows shielding EMFs of man-made origin in the entire frequency range. At the same time, the small thickness of the coating makes it possible to coat surfaces of any configuration without changing their shape. The developed mixtures minimize the reflection coefficients of electromagnetic waves along with a sufficient shielding coefficient. This helps to avoid an increase in the electromagnetic background in buildings due to the reflection of electromagnetic waves.

The developed noise-protective composite materials based on foam latex and expanded polystyrene allow for high noise reduction indices in the entire sound range. A particularly important result is the reduction of low-frequency noise levels (by 12–30 dB), which is practically not absorbed by building materials and structures. The addition of 5–10% magnetite to the mixture allows for simultaneous shielding of acoustic and electromagnetic fields.

Studies have shown that LED ultraviolet radiation sources can be used in the presence of people for at least 8 hours without reaching the maximum permissible exposure level of 30J/m^2 according to SBM-2015. The use of LED ultraviolet radiation sources allows to increase the concentration of ions in deionized air to the standard concentration (500cm^{-3}) within 10 minutes according to SBM-2015. At the same time, the number of colonies of fungal forming units is reduced by 2,3 times and the total microbial number by 2,8 times. The advantage of LED ultraviolet radiation sources is the ability to connect to standard indoor lighting sources and practical invisibility to the eye due to their small size, which is important for use in buildings of historical significance.

The scientific novelty of the obtained research results is the development of liquid composite materials with adjustable shielding coefficients of electromagnetic fields of a wide frequency range, suitable for application to surfaces of complex shapes; development of composite metal-polymer materials with high noise reduction indices and shielding coefficients of electromagnetic fields; substantiation of the use and determination of the effectiveness of LED ultraviolet radiation sources for ionization and air debacterization.

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