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Investigation of the Biostability of Magnesia Composites in the Simulated Environment of Mycelial Fungi Found in Construction Materials

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ABSTRACT

Numerous studies have examined corrosion in composite construction materials. and composites with cement and polymeric binders have been the most investigated. Material robustness with magnesia binders and millimeters needs additional research. The only known stability of mycelial fungus is amid continual dampness. These chemicals can promote microscopic development under adverse conditions. The metabolic byproducts of these organisms can modify material properties. This study examined magnesia composites' resistance to mycelial fungus breakdown in a simulated environment. focused on exoenzyme concentration during exposure. Several citric acid and hydrogen peroxide combinations in water were tested for biocorrosion potential. The experimental design matrix determined aggressive midrange component ranges. Caustic magnesite with salt chloride was investigated. The composites contained quartz. dolomite. pine sawdust. and sifting granite crushed stone. Composite biostability was measured by sample mass content and strength variations in hostile conditions. Assertive media damaged all composite compositions from the start of sample exposure. Dolomite-loaded magnesium composites withstand better. They need to be more durable. Magnesia composites can be used in biologically active constructions with particular protection. Graph-analytical methodologies and experimental planning were used to determine composite preference. The dolomite composite was the most durable. Monitoring mass content and resistance coefficient during tests can be used to evaluate composite quality using statistical processing.

1. INTRODUCTION

During operation, building materials and products are subjected to various adverse conditions, including physical, chemical, and biological influences. The mechanisms of biological corrosion are more intricate and include multiple stages, in contrast to "purely" corrosive processes generated solely by aggressive chemical media such as acidic, alkaline, and salt solutions [1-3].

Civil and industrial buildings and structures are the primary national economic objects affected by the impact of biocorrosion on materials. Microorganisms can colonise several materials, including metals, concrete, polymers, rubber, lacquered surfaces, and painted surfaces [4-6]. However, the biocorrosion of magnesia composites remains underexplored, despite their potential importance in construction. Understanding how these materials resist biological degradation is crucial for improving their durability and reducing their vulnerability to microbial attack, which can lead to significant economic losses in the construction sector.

So far, several studies have been conducted by both domestic and foreign experts to evaluate the biocorrosion and protection of cement [6-8]. Simultaneously, a limited amount of research is available on the biocorrosion of magnesia composites. This study aims to fill this gap by assessing the resistance of magnesia composites to fungal degradation, particularly focusing on metabolic products like organic acids and hydrogen peroxide produced by mycelial fungi. By investigating the biostability of these composites, we provide a clearer understanding of how magnesia-based materials can

be optimized to withstand biological corrosion. In this study, we assessed the resistance of magnesia stone to biological corrosion by measuring the extent of mould fungi Aspergillus niger spreading on the surface of the samples. The research was conducted in the mycology laboratory of the Kazan Research Institute of Epidemiology and Microbiology, affiliated with Rospotrebnadzor. The findings of this research highlight the potential impact of enhancing the fungal resistance of magnesia composites on building longevity. By improving the biostability of these materials, we can significantly reduce maintenance costs and improve the sustainability of construction projects. This study provides crucial insights into how improved resistance to fungal attack can lead to the development of more durable and sustainable building materials. These results will directly benefit the construction industry by promoting the use of materials better equipped to withstand microbial deterioration. The samples consisted of magnesia stone treated with sulphate and chloride treatment and Portland cement and gypsum composites. The method involves maintaining the samples contaminated with mould spores under optimal conditions for fungal growth, followed by evaluating the resistance of the coating to fungi on a 4-point scale (ranging from 0 to 3 points) (by GOST 28206, method 2). The strain utilised for the experiments was Aspergillus niger, obtained from VCM. Aspergillus niger is recognised as a highly effective agent in breaking down a wide range of industrial and construction materials. It is commonly employed as a test culture in many standard assessments for evaluating resistance to microorganisms, particularly mould fungi. The investigation revealed that chloro-magnesia stone had the maximum level of fungus resistance, scoring 0 points. On the other hand, sulfomagnesia stone and Portland cement demonstrated lower resistance levels. Gypsum stone samples were the most vulnerable to the dissemination of this particular type of mould.

The experimental findings [9, 10] indicate that increasing the concentration of the solutions used to activate the hydration of magnesia cement results in an increase in the resulting material's fungal resistance. The kind and amount of hydration phases in hardened magnesia stone are determined by the type and concentration of the activator used [11, 12]. Considering the significant role that fungal resistance plays in ensuring the durability of building materials, this study provides important data on the impact of phase composition and activator concentration on the biostability of magnesia composites. These insights will contribute to more effective material design, particularly in environments prone to microbial activity.

The study [13] aims to create a magnesium hydroxide covering with enhanced capabilities to safeguard concrete against Microbiologically Induced Corrosion. Accelerated sulphuric acid spraying tests of varying durations assessed the anti-corrosion capabilities of the coating. Pull-off and Scanning Electron Microscopy (SEM) analytical measurements determined the coating's satisfactory adhesion capacity. The protective efficacy of this coating was assessed by monitoring the formation of gypsum, the primary corrosion product of concrete, by X-ray Diffraction (XRD) analysis and Attenuated Total Reflectance (ATR) measurements. Furthermore, a lengthy acid spraying test was conducted to assess the performance of the coating under conditions that closely resemble those seen in an actual sewer pipe. The results of this test demonstrated that the coating can provide extended protection to the concrete substrate [13].

The most corrosive fungi include those belonging to the genera Aspergillus, Penicillium, Saccharomyces, Chrysospori-ummerdarium, Talaromyces flavus, Venustampullaparva, and Cladosporium herbarium species [14-16]. Aspergillus niger is a prevalent fungal strain [17]. Several investigations have demonstrated that A. niger can actively participate in the corrosion process of titanium, carbon steel, and magnesium alloy [17-19]. The study [10] showed that A. niger greatly expedited the corrosion process of AZ31B magnesium alloy during the initial phases, but the rate of acceleration decreased after that. The presence of A. niger on the magnesium alloy caused the occurrence of pitting corrosion [20].

Mould fungi biodegrade building materials and products due to the mechanical damage caused by mycelium growth and the main effects of metabolic products, including exoenzymes, organic acids, and reactive oxygen species (ROS), such as hydrogen peroxide [21-23]. Every microorganism has a diverse set of enzymes, which vary in their unique characteristics and aggressiveness. These factors govern the microorganism's metabolic activity, selectivity towards nutrients, and function in the natural cycle of substances and decomposition.

Building materials undergo degradation due to enzymatic effects through various processes, including oxidation, reduction, decarboxylation, esterification, hydrolysis, and others. The numbers are 2 and 28. The products resulting from the catalytic action of hydrolases (enzymes that use water), lyases (catalysts that break down complex molecules into simpler compounds), and oxidoreductases (enzymes that catalyse redox processes) have a highly potent destructive impact on most materials. Peroxidase and catalase, belonging to the class of oxidoreductases, exhibit distinct modes of operation [24]. Peroxidase facilitates the oxidation of diverse organic molecules, including enzymes, amines, and heterocyclic compounds, using hydrogen peroxide as a catalyst. Fungi belonging to the genera Penicillium, Aspergillus, Fusarium, Alternaria, Cladosporium, etc., exhibit notable peroxidase activity in their mycelial form. Catalase speeds up the decomposition of hydrogen peroxide into water and molecular oxygen. It also catalyses the oxidation of different alcohols and other molecules by peroxides. Penicillium fungi are active makers of catalase. There is a direct relationship between the type of material impacted and the enzymes of the agents responsible for the destruction.

Organic acids are the most potent aggressive metabolites produced by microbes. A study conducted in the range of 27 to 32 has demonstrated the isolation of over 40 distinct varieties of organic carboxylic acids, with one, two, or three primary groups, from cultures of mould fungi. The metabolites of microorganisms contained oxalic, citric, acetic, succinic, lactic, tartaric, fumaric, and gluconic acids. Simultaneously, the identical species of mycelial fungi can produce a range of related acids. Penicillium fungi primarily produce citric and gluconic acids, whereas Aspergillus fungi produce citric, gluconic, and oxalic acids. Mucor fungi, on the other hand, produce succinic, fumaric, and oxalic acids.

Understanding the processes by which materials degrade due to the byproducts of metabolism is crucial. Even materials that are somewhat resistant to fungi can still undergo biodegradation and experience a decline in their physical and mechanical properties when exposed to metabolites produced by fungi growing on nearby non-resistant materials. Despite their inherent resistance to fungi, these materials can still

undergo biodegradation when exposed to aggressive exometabolites [25].

Organic acids and hydrogen peroxide play a crucial part in the breakdown of building materials as aggressive metabolites generated by microscopic fungi throughout their growth. For instance, in the case of polymeric materials, it is established that organic acids released by fungi during biodegradation play a direct role in the acid hydrolysis of chemical bonds. These acids also contribute to the acidification of the surrounding environment, creating an optimal pH zone for the activity of other aggressive metabolites, such as exoenzymes. Hydrogen peroxide can oxidise different chemical groups in polymeric materials, causing alterations in their chemical composition and structure [21-30].

The metabolites generated by decomposer fungi facilitate the biodegradation of materials and contribute to the deterioration of their physical and chemical properties. Furthermore, alterations in the physical and chemical properties might manifest before the visible identification of the biodegradation of building and industrial materials. Identifying the specific metabolites produced by fungi that contribute to changes in the physical and technical properties of magnesia composites is crucial. This knowledge is essential for accurately predicting the extent of biocorrosion in various material compositions. This will enable the estimation of the susceptibility of magnesia composites to undergo bio-deterioration processes and identify the technical qualities that deteriorate more significantly under these conditions.

This study aimed to investigate the biological durability of magnesia composites in simulated settings containing organic acids and hydrogen peroxide. These environments mimic the hostile metabolites produced by mycelial fungus, which can affect the performance of materials at various exoenzyme concentrations.

The research aims to achieve specific goals or objectives. To examine the resistance of magnesia composites to mycelial fungus in a controlled experimental setting; To confirm the levels of hostile substances in the water-based solution of the biological environment; To design an experimental study plan including citric acid and hydrogen peroxide in an aqueous solution of aggressive media, it is necessary to consider the varying concentrations of these substances. This can be achieved by utilising mathematical methods of experiment planning and mathematical statistics. Measure the quantitative durability indices of unfilled and filled magnesia composites in model media with varying concentrations throughout time trials. To evaluate the quality of test composites containing both inorganic and organic fillers and to provide a graph-based analytical method for deriving numerical quality metrics of these composites. Enable the visualisation of experimental data to verify the suitability of the suggested composite quality measures.

2. MATERIALS AND METHODS

The magnesia composites were manufactured using the following constituent components: caustic magnesite from the Satkinsky deposit, grade PMK-75; an aqueous solution of bischofite ($MgCl_2$) with a density of 1.25 g/cm^3; an aqueous solution of magnesium sulphate ($MgSO_4$) with a density of 1.25 g/cm^3; magnesium sulphate ($MgSO_4$) used as an additive; fillers including quartz sand of 0.16-0.315mm fraction, dolomite from the Issinsky deposit in the Penza region of the same fraction, and screening of high-strength crushed stone from the Minyarsky deposit, also of the 0.16-0.315mm fraction.

The optimal ratio of binder to filler was identified through experimental investigation for each type of concrete composition in magnesia composites. Simultaneously, it was deemed optimal to maintain a ratio that would result in the desired mobility of the produced combination. Experimental evidence has shown that to ensure the ability to lay the mixtures obtained in floor coverings; the mobility index should fall within 11-17 cm (according to GOST 310.4-81). For comparison, samples were prepared without any filler or additives, using a ratio of bischofite to magnesite of 1:1.5. Unfilled compositions were used as control samples compared to the ones above. In this situation, the ratio of caustic magnesite to bischofite was presumed to be 1:1.

Research was conducted, and samples of the compositions listed in Table 1 were produced.

Table 1. Compositions of magnesia composites

Components	Content of Mass Parts in Formulations				
	1	2	3	4	5
Caustic magnesite	100	50	50	50	50
Aqueous bischofite solution	100	50	50	50	50
Quartz filler	-	100	-	-	-
Dolomite filler	-	-	100	-	-
Pine sawdust	-	-	-	50	-
Crushing sands of high-strength crushed stone	-	-	-	-	100

The fabrication of composites based on caustic magnesite involved using the following technology: the ratios of binder/filler (bischofite/magnesite) were selected, and the quantitative content of each component was determined accordingly. Next, the dry components, which include caustic magnesite and filler, were mixed extensively. Subsequently, a solution of bischofite was introduced into the active mixer, and the composites were mixed until a uniform mixture was achieved.

The combination was used to shape samples measuring 1 × 1 × 3 cm. These samples were then incubated for seven days under standard temperature and humidity settings. Subsequently, they were introduced into a simulated biological environment.

The biostability of composites was assessed by measuring the changes in mass content and strength of the materials when they were exposed to a solution containing metabolic products of mycelial fungi. Several mixtures of citric acid and hydrogen peroxide were utilised as pure chemicals for experimental experiments. These compounds are potential biocorrosion agents, as they are mycelial fungi's most commonly produced metabolites during the deterioration of diverse building materials. The estimated production intervals of these chemicals by mycelial fungi, as stated in references [15, 16],

are as follows: for citric acid - 0.02-0.2 mol (or 0.1-10%); for hydrogen peroxide - 0.01-0.1 mol (or 0.03-3%). In light of the aforementioned, research was conducted to determine the optimal mix of citric acid and hydrogen peroxide that would result in the most significant corrosion damage to composites on magnesia binder with various fillers. The composition of the biological medium was altered. The problem was resolved by implementing the planning matrix, namely the Kono plan consisting of 9 trials. The varied elements in this matrix were the concentration of citric acid (X1) and hydrogen peroxide (X2) in the aqueous solution. The planning matrix generated for the conducted experiment is displayed in Table 2.

Table 2. Experiment planning matrix

No. of Items	Planning Matrix		Working Matrix		Content of Components in Aqueous Solution	
	X_1	X_2	Citric Acid, mol	Hydrogen Peroxide, mol	Citric Acid ++ H_2O g.	6% Peroxide Hydrogen + + H_2O g.
1	0	0	0.2	0.1	1.92+88.8	3+57
2	+1	+1	2.0	1.0	19.2+80.8	3+3
3	-1	+1	0.02	1.0	0.19+99.8	3+3
4	-1	-1	0.02	0.01	0.19+99.8	3+597
5	+1	-1	2.0	0.01	19.2+80.8	3+597
6	+1	0	2.0	0.1	19.2+80.8	3+57
7	0	+1	0.2	1.0	1.92+88.8	3+3
8	-1	0	0.02	0.1	0.19+99.8	3+57
9	0	-1	0.2	0.01	1.92+88.8	3+597

3. RESULTS AND DISCUSSION

The results of the study of the durability of the above composites are given below (Tables 3-7).

Table 3 shows the changes in mass content and durability coefficient during ageing in model media of unfilled magnesia composites.

The changes in mass content and durability coefficient when aged in model media of magnesia composites filled with silica sand are shown in Table 4.

The changes in mass content and durability coefficient when aged in model media of magnesia composites filled with dolomite are shown in Table 5.

The changes in mass content and durability coefficient when aged in model media of magnesia composites filled with pine sawdust are shown in Table 6.

Change of mass content and coefficient of durability at soaking in model media of magnesia composites filled with granite crushing sands is shown in Table 7.

According to the data of Tables 3-7 the diagrams of change of mass content and resistance coefficient are constructed. They are shown in Figures 1-5.

Figure 1 shows the diagrams of change of mass content and resistance coefficient of composites without fillers.

Figure 2 shows the diagrams of changes in mass content and resistance coefficient of composites filled with silica sand.

Table 3. Experimental results of curing composites without filling of magnesia composites

No.	Change in Mass Content after Holding Time, %			Change of Resistance Coefficient after Holding Time, Relative Unit		
	30 days	60 days	90 days	30 days	60 days	90 days
1	5.37	7.02	8.25	0.52	0.41	0.24
2	–	–	–	0.01	0.01	0.01
3	4.93	6.49	7.50	0.86	0.61	0.35
4	4.56	5.95	8.24	0.25	0.15	0.15
5	1.83	4.59	6.41	0.86	0.61	0.30
6	–	–	–	0.01	0.01	0.01
7	4.42	6.27	8.47	0.50	0.42	0.20
8	5.10	5.56	6.35	0.37	0.14	0.08
9	9.80	5.50	6.17	0.37	0.28	0.14

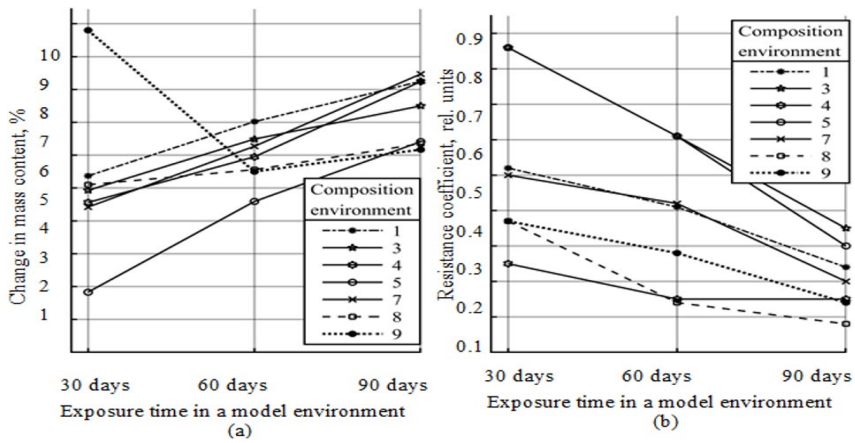

Figure 1. Changes in mass content (a) and resistance coefficient (b) of magnesia composites without filling in aggressive media of different composition

Table 4. Experimental results of ageing in model media of magnesia composites filled with silica sand

No.	Change in Mass Content after Holding Time, %			Change of Resistance Coefficient after Holding Time, Relative Unit		
	30 days	60 days	90 days	30 days	60 days	90 days
1	2.26	2.66	2.99	0.24	0.07	0.06
2	–	–	–	0.01	0.01	0.01
3	0.57	1.99	2.38	0.35	0.01	0.01
4	-0.01	1.99	2.53	0.10	0.00	0.00
5	1.67	1.90	2.63	0.35	0.01	0.01
6	–	–	–	0.01	0.01	0.01
7	-1.14	2.75	3.42	0.17	0.04	0.03
8	0.14	2.10	3.06	0.13	0.02	0.01
9	1.13	2.58	3.71	0.19	0.01	0.01

Table 5. Experimental results of ageing in model media of magnesia composites filled with dolomite

No.	Change in Mass Content after Holding Time, %			Change of Resistance Coefficient after Holding Time, Relative Unit		
	30 days	60 days	90 days	30 days	60 days	90 days
1	13.94	1.69	2.86	0.36	0.23	0.16
2	–	–	–	0.01	0.01	0.01
3	1.57	3.93	5.51	0.53	0.23	0.12
4	1.18	2.90	4.68	0.21	0.06	0.05
5	1.65	5.13	5.25	0.53	0.23	0.13
6	–	–	–	0.01	0.01	0.01
7	-0.89	4.69	5.32	0.33	0.26	0.13
8	1.99	3.34	4.56	0.18	0.08	0.06
9	1.99	3.44	5.06	0.29	0.06	0.04

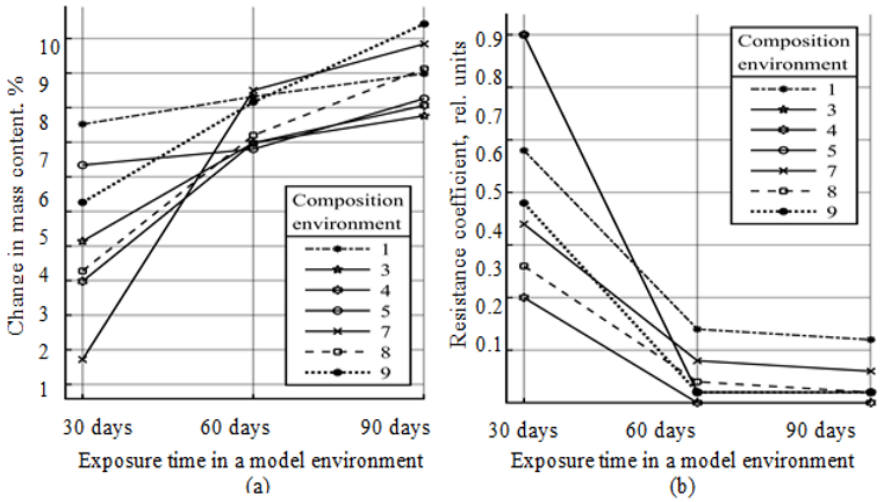

Figure 2. Changes in mass content (a) and resistance coefficient (b) of composites filled with silica sand in aggressive media of different composition

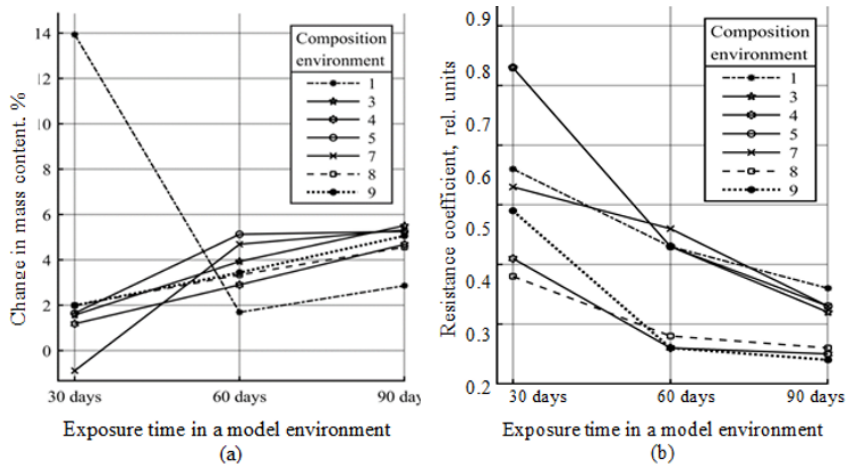

Figure 3. Changes in mass content (a) and resistance coefficient (b) of composites filled with dolomite in aggressive media of different composition

Table 6. Results of curing experiments in model media of magnesia composites filled with pine sawdust

No.	Change in Mass Content after Holding Time, %			Change of Resistance Coefficient after Holding Time, Relative Unit		
	30 days	60 days	90 days	30 days	60 days	90 days
1	8.65	14.19	16.33	0.84	0.75	0.46
2	–	–	–	0.01	0.01	0.01
3	9.11	12.04	11.53	0.66	0.35	0.18
4	7.66	10.27	12.70	0.19	0.09	0.06
5	5.89	8.81	13.30	0.66	0.35	0.21
6	–	–	–	0.01	0.01	0.01
7	13.66	12.51	13.63	0.59	0.49	0.29
8	8.85	10.47	12.76	0.31	0.20	0.11
9	9.25	11.66	11.83	0.43	0.34	0.16

Table 7. Experimental results of curing in model media of magnesia composites filled with high-strength crushed stone sands

No.	Change in Mass Content after Holding Time, %			Change of Resistance Coefficient after Holding Time, Relative Unit		
	30 days	60 days	90 days	30 days	60 days	90 days
1	6.30	2.60	2.75	0.30	0.12	0.05
2	–	–	–	0.01	0.01	0.01
3	0.49	1.67	2.27	0.44	0.16	0.09
4	0.14	1.02	1.03	0.15	0.05	0.03
5	-0.63	1.96	2.09	0.44	0.16	0.09
6	–	–	–	0.01	0.01	0.01
7	0.61	1.95	3.15	0.21	0.07	0.05
8	0.51	1.26	2.47	0.14	0.04	0.00
9	1.31	1.79	2.14	0.24	0.02	0.02

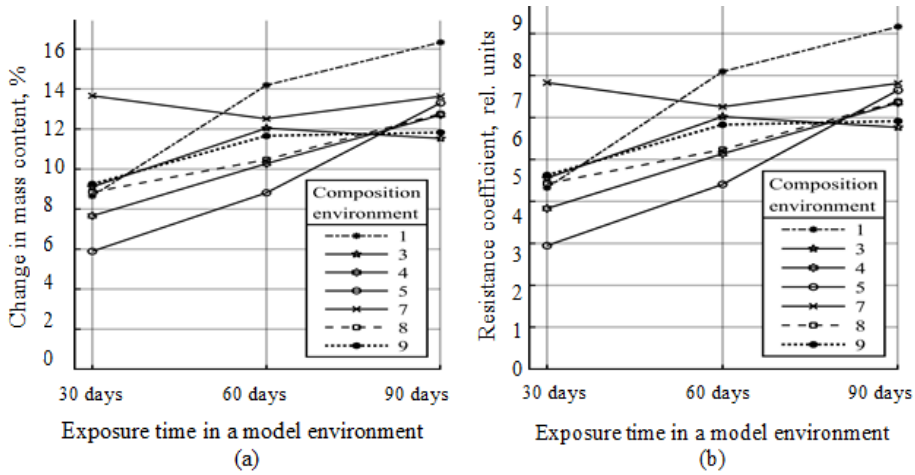

Figure 4. Changes in mass content (a) and resistance coefficient (b) of composites filled with pine sawdust in aggressive media of different composition

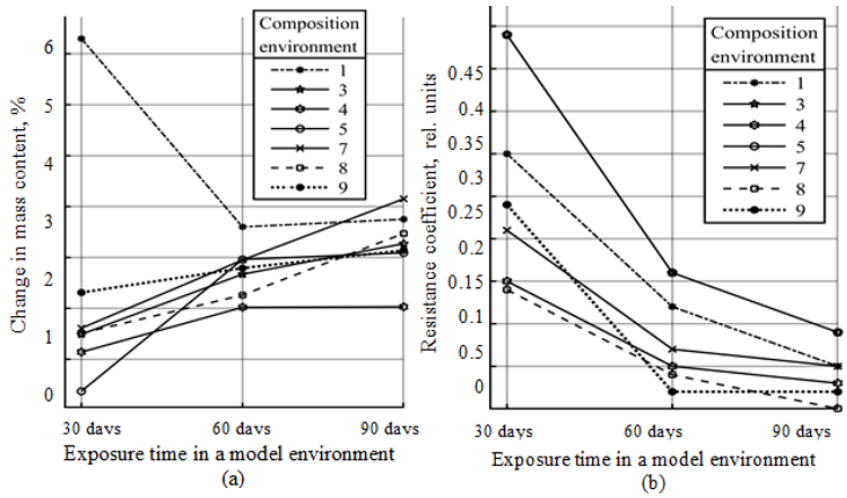

Figure 5. Changes in mass content (a) and resistance coefficient (b) of composites filled with high-strength crushed stone crushing sands in aggressive media of different composition

Figure 3 shows the diagrams of changes in mass content and resistance coefficient of composites filled with dolomite.

Figure 4 shows the diagrams of changes in mass content and resistance coefficient of composites filled with pine sawdust.

Figure 5 shows diagrams of changes in mass content and resistance coefficient of composites filled with high-strength crushed stone sands.

The analysis of experimental data (Tables 3-7) and the given diagrams (Figures 1-5) allowed us to propose a graph-analytical approach to quantitative assessment of the quality of magnesia composites aged for 30, 60, and 90 days and generally for a given period of time, but not less than three periods. We call this quantitative assessment a metric.

Figure 6 shows two graphical dependences of compositions numbered 1 and 5 filled with dolomite, relative to which the initial explanatory calculations for further calculation of the metric - a quantitative assessment of the quality of test magnesia composites at a change in their mass content in per cent (%).

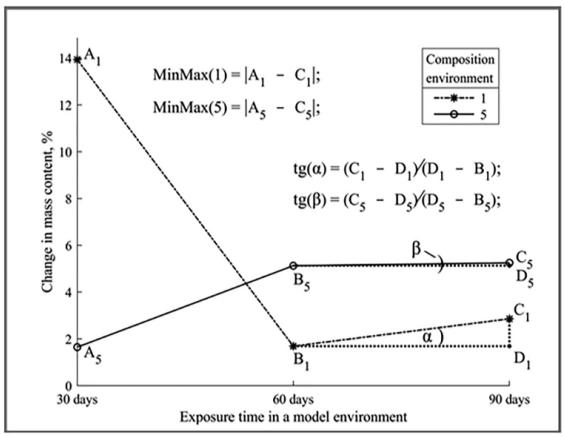

Figure 6. Determination of preliminary indicators for calculating the metric quality assessment metric for magnesia composites

Figure 6 shows two graphical dependences of compositions numbered 1 and 5 filled with dolomite, relative to which the initial explanatory calculations for further calculation of the metric - a quantitative assessment of the quality of test magnesia composites at a change in their mass content in per cent (%).

Figure 7 shows the functional diagram in the form of an algorithm for calculating the quality assessment metric for test (magnesia) composites.

Calculations were performed to determine the quality metrics of the test composites, according to Figures 6 and 7. Table 8 shows the results of the evaluation of the change in mass content and durability coefficient of the composition without filler.

Based on the metrics provided in Table 8, the aggressive solution of composition No. 9 exhibits the most substantial change in mass content. Therefore, even a tiny change in the mass content can be observed in composition No. 8 of the aggressive medium. Aggressive medium No. 8 has the mildest composition among all other aggressive media compositions. Based on the provided metrics of resistance coefficient change, the aggressive medium number 4 exhibits the most substantial alteration in the resistance coefficient for the analysed composition. Simultaneously, the resistance coefficient experiences the most minimal alteration in medium number 5.

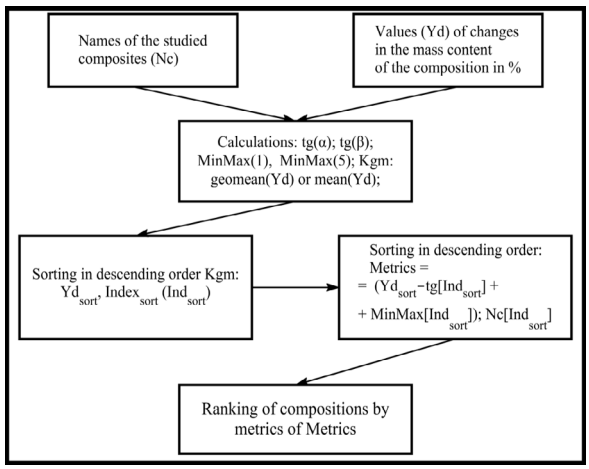

Figure 7. Functional scheme for calculating the quality metric of test composites

Table 9 displays the outcomes of assessing the alteration in mass content and resistance coefficient of composites containing quartz sand.

According to the data of Table 9, it can be seen that the most significant change in mass content of samples occurs in composition No. 7 of the aggressive medium and the least - in composition No. 5. The composition of aggressive medium #5 is less aggressive compared to other compositions of aggressive media. According to the given metrics of change in the resistance coefficient, we note that the most significant change in the resistance coefficient occurs when the samples are aged in the composition of aggressive medium number 4, and the slightest change in the resistance coefficient is characteristic of aggressive media compositions 3 and 5.

Table 10 gives the results of evaluating the change in mass content and resistance coefficient of compositions filled with dolomite.

Table 8. Results of quality assessment of the formulation without filler by metrics of mass content change and resistance coefficient

Ranking of Compositions by Mass Content Change Metric			Ranking of Formulations by Metric Change in Resistance Factor		
No. of Items	**Compositions of Aggressive Media**	**Mass Content Change Metric**	**No. of Items**	**Compositions of Aggressive Media**	**Metric of Change in the Coefficient of Resistance**
1	9	9.888267	1	4	10.000000
2	1	8.425195	2	9	3.785841
3	7	8.018663	3	8	3.337368
4	3	7.774187	4	1	2.914496
5	4	7.459268	5	7	2.656236
6	5	6.536075	6	3	1.520273
7	8	6.106850	7	5	1.374816

Table 9. Results of quality assessment of quartz sand-filled formulations by metrics of mass content change and resistance coefficient

Ranking of Compositions by Mass Content Change Metric			Ranking of Formulations by Metric Change in Resistance Factor		
No. of Items	**Compositions of Aggressive Media**	**Mass Content Change Metric**	**No. of Items**	**Compositions of Aggressive Media**	**Metric of Change in the Coefficient of Resistance**
1	7	6.095064	1	4	10.000000
2	9	3.661519	2	8	8.312811
3	1	3.019512	3	7	7.112948
4	8	2.925361	4	9	5.555556
5	3	2.812414	5	1	5.524781
6	4	2.369253	6	3	2.941176
7	5	2.258346	7	5	2.941176

Table 10. Results of quality assessment of dolomite-filled compositions by metrics of mass content change and resistance coefficient

Ranking of Compositions by Mass Content Change Metric			Ranking of Formulations by Metric Change in Resistance Factor		
No. of Items	**Compositions of Aggressive Media**	**Mass Content Change Metric**	**No. of Items**	**Compositions of Aggressive Media**	**Metric of Change in the Coefficient of Resistance**
1	1	13.979164	1	8	8.203117
2	7	8.390767	2	4	6.216692
3	5	7.022041	3	1	4.617587
4	3	5.599524	4	7	4.365935
5	9	4.709773	5	9	3.971841
6	8	4.467847	6	5	2.352289
7	4	4.240627	7	3	2.288842

Table 11. Results of quality assessment of formulations filled with pine sawdust by metrics of mass content change and resistance coefficient

Ranking of Compositions by Mass Content Change Metric			Ranking of Formulations by Metric Change in Resistance Factor		
No. of Items	**Compositions of Aggressive Media**	**Mass Content Change Metric**	**No. of Items**	**Compositions of Aggressive Media**	**Metric of Change in the Coefficient of Resistance**
1	1	18.148446	1	4	7.517340
2	9	13.256135	2	8	4.606861
3	3	12.724125	3	9	3.110625
4	4	12.606953	4	7	2.580416
5	8	12.194184	5	5	1.995773
6	7	12.165658	6	3	1.855650
7	5	11.757192	7	1	1.748527

Table 12. Results of quality assessment of formulations filled with high-strength crushed stone crushing sands by metrics of mass content change and resistance coefficient

Ranking of Compositions by Mass Content Change Metric			Ranking of Formulations by Metric Change in Resistance Factor		
No. of Items	**Compositions of Aggressive Media**	**Mass Content Change Metric**	**No. of Items**	**Compositions of Aggressive Media**	**Metric of Change in the Coefficient of Resistance**
1	1	6.958079	1	4	8.249706
2	5	3.961664	2	8	7.022472
3	7	2.893191	3	7	6.180282
4	3	2.409267	4	9	4.545455
5	9	2.192035	5	1	3.868246
6	8	1.916485	6	3	2.755178
7	4	1.407864	7	5	2.755178

According to the data of Table 10, we determine that the most significant change in mass content is characteristic of the samples aged in the composition of aggressive medium № 1 and the least—in composition № 4. The most significant change in the resistance coefficient occurs in the composition of the aggressive medium designated under the number 8 and the least—in composition № 3. Composition number 3 is less aggressive; samples filled with dolomite in this composition are characterized by a better (higher) resistance coefficient.

The results of the evaluation of the change in mass content and resistance coefficient of the compositions filled with pine sawdust are given in Table 11.

It follows from Table 11 that the most significant change in the mass content of samples occurs in the composition of aggressive medium № 1 and the least in composition № 5. According to the given metrics of change of resistance coefficient, the most significant change of resistance coefficient occurs in the composition of aggressive medium, designated as number 4, and the least in composition №1.

Table 12 gives the results of the evaluation of the change in mass content and resistance coefficient of the compositions filled with high-strength crushed stone sands.

Based on the findings shown in Table 12, the composition of aggressive medium number 1 experiences the most significant change in mass content, whereas composition number 4 experiences the slightest shift in mass content. Based on the provided data on the change in the resistance coefficient, the most notable change in the resistance coefficient occurs in the aggressive medium composition labelled as number 4. On the other hand, the least significant change in the resistance coefficient was observed when the samples filled with granite crushed stone sands were aged in compositions 3 and 5.

Therefore, research has determined the long-lasting nature of unfilled and filled magnesia composites in a simulated environment containing byproducts from the metabolic processes of mycelial fungi. Based on the resistance coefficient after 90 days of exposure, the compositions investigated can be ranked in the following order, based on the decrease in the index: high-strength crushed stone, quartz filler, dolomite filler, unfilled composite, and pine sawdust.

Overall, it is possible to categorise compositions of aggressive environments into two groups: numbers 3 and 5. In these compositions, one group has a minimum amount of citric acid and a higher concentration of hydrogen peroxide, while the other group has the opposite. These compositions exhibit more noticeable changes in the resistance coefficient of all the magnesia composites considered.

The impact of citric acid content in a model medium on the biostability of mineral building materials was examined in the study [31]. Analysis of the acquired kinetic dependencies reveals a reduction in the strength characteristics of cement-sand mortars during exposure to the model mixture, indicating the occurrence of sample degradation. The linear nature of the established dependencies, rather than the initially presumed polynomial nature, is elucidated by the observation that from the second day of the kinetic experiment, the rate of interaction processes (complex formation) between the components of the model medium and the cement-sand mortar samples stabilizes to an almost constant level. After removing Ca_2^+ salts from the samples, they react with the carboxylic acids present in the medium, forming water-insoluble calcium oxalate and citrate salts. As calcium salts are liberated into the medium, fine-crystalline quartz sand detaches from the vertically positioned samples of cement-sand mortars. It descends to the bottom of the test tank within the kinetic apparatus. Consequently, new surface regions of the cement-sand mortar samples are exposed to environmental interaction, and the interaction process with the model environment persists again. The total area of all cement-sand mortar samples involved in the interaction with a fixed volume of the model environment remains virtually unchanged over eight days, indicating a constant rate of interaction between the calcium salts of the cement-sand mortars and the components of the model environment, as well as a linear relationship in the kinetic dependencies of the reduction in strength characteristics.

The biostability of cement-sand mortars is influenced not only by the type of Portland cement and the duration of exposure in the model environment but also by its chemical composition, as indicated by the data on the variation in strength characteristics of cement-sand mortars [31]. The loss of strength values for cement-sand mortars, both in bending and compression, following exposure to the model environment of the acid combination and to individual citric acid, are notably similar. The reduction in flexural strength of cement-sand mortars utilizing Portland cement M400 CEM II/A-P 32.5 N is 68.2% in a model environment and 74.2% in a citric acid environment. The reduction in compressive strength of cement-sand mortars utilizing Portland cement M500 CEM I 42.5 N is 51.4% in a model environment and 54.9% in a citric acid environment. Simultaneously, it is essential to observe that the strength loss values of cement-sand mortars, both in bending and compression, following exposure to a singular acetic acid environment, were markedly lower than those in the model environment of the acid mixture. Analysis of kinetic data indicates that the primary factor in the biodeterioration of cement-sand mortars, when subjected to a model environment of three acids, is likely a combination of citric and oxalic acids, demonstrating a synergistic effect.

The media with the greatest concentration of citric acid, equal to 2.0 moles, and hydrogen peroxide, ranging from 0.1-1.0 moles, were shown to be the most aggressive. In these media, unfilled composite samples deteriorated after a 30-day exposure period. The composites' resistance can be enhanced by incorporating active additives into the compositions.

4. CONCLUSIONS

1. This paper presents the research findings on the resistance of magnesia composites in a simulated environment of metabolic products from mycelial fungi, including an aqueous solution of citric acid and hydrogen peroxide.

2. The aqueous solution for testing contained citric acid (0.1-10%) and hydrogen peroxide (0.03-3%), which was justified based on the available literature on biotechnology.

3. A planning matrix, known as the Kono plan, was created to assess the longevity of magnesia composites in aqueous solutions containing varying percentages of citric acid and hydrogen peroxide. The matrix consisted of 9 experiments.

4. The study presents the experimental and computer processing of resistance indices of magnesia composites with various fillers and without fillers that have been aged in a simulated harsh environment.

5. The impact of fillers on the durability of magnesia composites in the byproducts of mycelial fungus metabolism is assessed.

6. Magnesia composites loaded with dolomite have been found to exhibit more excellent resistance to the effects of hostile substances.

7. A graph-analytical method is suggested for computing the quantitative metrics of quality evaluation for the studied composites after being exposed for 90 days.

8. The composite quality assessment measures align with experimental results and their visual depiction.

9. The method above can be expanded to evaluate the quality of composites by monitoring the variations in mass content and resistance coefficient over various interval long-term tests.

10. While the current study provides valuable insights into the biostability of magnesia composites, further research is needed to explore additional aspects of these materials. First, future studies could investigate the long-term effects of varying environmental conditions, such as temperature fluctuations, humidity, and exposure to different fungal species, on the durability of magnesia composites. This would offer a more comprehensive understanding of their performance in real-world settings.

Additionally, the impact of different types of organic and inorganic fillers on the fungal resistance of magnesia

composites warrants further exploration. Understanding the role of various additives could lead to the development of enhanced formulations that provide even greater biostability.

Moreover, extending the research to include other microbial species, not just Aspergillus niger, could offer insights into the broader spectrum of microbial degradation mechanisms that affect magnesia-based materials. This would help in designing composites that are resilient across diverse microbial environments.

Finally, the development of advanced coatings or surface treatments that could further improve the biostability of magnesia composites is recommended. Research into protective coatings that can be easily applied to existing structures may provide a cost-effective solution for enhancing the lifespan of buildings and infrastructure.

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