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# IMPACT OF BIOCORROSION ON THE DURABILITY OF ETICS AND EMPIRICAL FINDINGS ABOUT THE PERIODOCITY OF MAINTENANCE

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## ABSTRACT

*Generally, the role of living organisms (especially bacteria, cyanophytes, algae and fungi) in the physical and chemical processes of the biocorrosion of an external thermal insulation composite system (ETICS) is underestimated. These organisms are the ones that are responsible for a wide range of changes in or "diseases" of building materials and constructions, including damage to a building´s appearance or the destruction and complete collapse of the characteristics and requirements of materials and the ETICS construction.*

*The following article concerns the impact of biological factors on the durability of ETICS. It shows the importance of and necessity to maintain it, and the method and periodicity of the maintenance.*

## KEY WORDS

- *Maintenance,*
- *external thermal insulation composite system (ETICS),*
- *biocorrosion facades, crustation of building material,*
- *ETICS life cycle.*

## 1. INTRODUCTION

The effectiveness of insulation is measured by various scientific and expert calculations. Insulation mainly reduces heating expenses, expands the lifespan of external walls and saves money that would have been used for the maintenance of the original external walls (renewal of paint coats, plaster, etc.)

Under ideal macroeconomic and microeconomic conditions, the return on the investment from the insulation of a building is presumed to be 20-30 years. The savings on the maintenance of the original walls can reach up to 30% of the investment in insulation.

At the same time, the manufacturers of insulation systems present in their technical specifications the notion of minimal maintenance – "if needed"– without any suggestions as to the technology, execution and periodicity of the maintenance needed.

The study of the impact of biocorrosion on building materials is difficult because it requires interdisciplinary solutions. The problem of changes in the lifespan of buildings and construction materials due to microorganisms has been considered by experts in concrete constructions, historical buildings and stone facades. There are various works and studies on the impact of microorganisms and their chemical and photosynthetic processes on a surface (Kapusta, M., 1999) and (Kapusta, M., Kováčik Ľ., 2000) and works on the decontamination technology of constructions (Sedlbauer, K., et al., 2007), and (Wasserbauer, R., 2000). According to (Wasserbauer, R., 2000) the biocorrosion and bioerosion of construction materials are primarily caused by water, changes in temperature, and the chemical solutions produced by microorganisms during chemosynthesis and photosynthesis.

Experts from the Faculty of Natural Sciences (FNS) at Comenius University in Bratislava have considered the biodegradation of historical buildings in more detail, as part of the VEGA 1/4182/97 project, led by prof. Ľubomír Kováčik. Their aim, however, was to introduce a range of cyanophytes and algae existing on the building stones of cultural landmarks and show their deteriorating effects (Kapusta, M., Kováčik Ľ., 2000) and (Uher, B., 2003).

The basic causes of the creation of algae on an external wall with ETICS are considered to be the life conditions of microorganisms, the external environment, the materials used for the basis of the ETICS and the quality of the technology for its execution (Blaich, J. 2000).

The exact effects and damage caused by algae and other microorganisms on ETICS is described by the Swiss Federal

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Laboratories for Materials Science and Technology (EMPA), which is an interdisciplinary research and services institution for material sciences and technology developments). Raschle and Büchli (2006) consider the principles of the creation of algae but also analyse possible repairs and maintenance. They have presented their 20 years of experience dealing with ETICS damaged by microorganisms. They state that the most effective method is regular control and protection, but the periodicity or durability of the treatment is not quantified.

The impact of microorganisms and the sanitation methods used for constructions are also considered by experts in projects and the technology of buildings made from concrete (Bilčík, J., Dohnálek, J., 2003). The sanitation methods are limited to changing the pH of the environment or protecting a construction against humidity. Prevention is handled by a protective hydrophobic or biocide coating.

Experiments domestically and abroad show that the most effective method for the destruction of algae and their prevention on an external wall is regular decontamination with the use of a biocide product. However, there are also negative elements to the decontamination of microorganisms by chemical products. Experts have concluded that despite the fact that there is no other regular protection of external walls other than with biocides, they cannot be considered a final solution because there is the probability that they will have negative effects on the environment. But the periodicity of the decontamination was not quantified by the experts.

The technologies for the removal of algae by effective chemical and conservation materials are considered in (Helmuth, V., 2011) in a practical manual for users and caretakers. It sets out several technologies for the protection of constructions against humidity. However, the durability of the intervention is not stated.

Damage to and changes in the characteristics of various construction materials caused by microorganisms have been shown through chemical analysis, scanning electron microscope devices (SEM), microbiological analysis and other specific diagnostic methods (Ledererová, J., 2009). The impact on the lifespan of ETICS has not, however, been observed or proven.

The above problems reveal the need to prove the impact of biocorrosion on the objective or actual durability of ETICS. It would be the first step in convincing building owners that regular maintenance is necessary to ensure the permanent resistance of ETICS against microorganisms and a building´s functioning.

## 2. MATERIALS AND METHODS

### 2.1 The impact of biocorrosion on the basic lifespan of etics

Every building or construction is ageing and deteriorating. The deterioration of a building is closely connected to its lifespan. A building´s lifespan is determined on the basis of the results of empirical observations and statistical data.

The lifespan of a construction is understood as the period from finishing the construction to the loss of its ability to be used for its intended purpose. The basic lifespan in each type of building is determined in Slovakia by the Slovak version of the STN 73 00 31 standard, but it expects good systematic maintenance. A building´s lifespan is calculated in years.

(Mandula, J., Tomko, M. 2003) have considered methods for determining the lifespan and deterioration of buildings, keeping in mind various influencing factors. They note that the impact of exterior factors, including the negative impact of biological factors, is not negligible.

The optimal life span of a building at a given time is determined on the basis of:

$$Z_S = K \cdot Z_Z \qquad (1)$$

where:

$Z_S$ is the determined lifespan of a building in years,

K – final constant of the factors influencing the probable (basic) lifespan,

$Z_Z$ – probable (basic) lifespan of a building in years.

The synergy of all the factors influencing the lifespan of a building or construction is further determined on the basis of:

$$K = k_1 \cdot k_2 \cdot k_3 \cdot k_4 \cdot k_5 \cdot k_6 \cdot k_7 \qquad (2)$$

where the constants $k_1$ $k_2$ $k_5$ and $k_6$ are set as the arithmetic mean of the constants shortening or extending the lifespan of the building or construction.

By multiplying these constants you get the probable (basic) lifespan of a building optimalised by actual observations through for example, inspections, construction enquiries, microbiological searches.

These factors impact the lifespan (Mandula, J., Tomko, M., 2003):

- Project solution ($\boldsymbol{k_1}$),
- Technology of construction ($\boldsymbol{k_2}$),
- Operation ($\boldsymbol{k_3}$),
- Maintenance ($\boldsymbol{k_4}$),
- Reconstruction of long-lasting elements ($\boldsymbol{k_5}$),
- External impacts ($\boldsymbol{k_6}$),
- Unexpected events ($\boldsymbol{k_7}$).

The external impacts ($\boldsymbol{k_6}$) influencing the lifespan of a building are:

- Physical (mechanical, thermal, moisture, UV rays),
- Chemical (aggressive water, atmosphere, gases, solutions)
- Biological (unwanted effects of living organisms and their products, effects of plants and trees).

The role of external impacts on the probable durability of buildings is not negligible because they act in combination with other factors.

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Pessimistic scenarios of decreases in the actual lifespan of buildings, taking into account the various impacts, has been considered in a study of the Building Testing and Research Institute in Slovakia (TSUS) for the mass construction of panel buildings (Briadka, P., Horečný, P., Sternová, Z., 2012). The factors influencing a basic or proposed lifespan are comparable to the factors used in the methods of (Mandula, J., Tomko, M., 2003). However, they excluded factors arising from damage to the structure or construction by unexpected events and the factors arising from completed reconstructions. The factors of maintenance and usage were considered in their maximum as well as minimum values. The pessimistic scenario shows a decrease in lifespan of 11-16 years (Briadka, P., Horečný, P., Sternová, Z., 2012).

The presented calculations (Mandula, J., Tomko, M., 2003) of the objective lifespan of buildings will be useful for determining the actual durability of constructions, for instance, with the ETICS composite insulation system and biocorrosion.

The presented methods (Mandula, J., Tomko, M., 2003) can be used in determining the actual lifespan of the parts of a construction, e.g., the external thermal insulation composite system (ETICS) with presumed biocorrosion or actual biocorrosion.

The method (Mandula, J., Tomko, M., 2003) also determines the intervals of the factors, e.g., the interval of a biological impact is between 0.71 and 1.00.

**Tab. 1** *Constant of surroundings´ impact (Mandula, J., Tomko, M., 2003).*

| **Surroundings** | $k_6$ |
|---|---|
| Very aggressive | 0.71-0.80 |
| aggressive | 0.81-0.90 |
| Slightly aggressive | 0.91-0.99 |
| Not aggressive | 1.00 |

The mathematical expression of the constant of the impact of a building´s surroundings is the arithmetic mean of the external impacts over time:

$$k_6 = \frac{k_{6\text{-}1} + k_{6\text{-}2} + k_{6\text{-}3}}{3} \tag{3}$$

where:

$k_6$ is the constant of the external impacts influencing the lifespan of buildings:

$k_{6\text{-}1}$ – physical impacts,

$k_{6\text{-}2}$ – chemical impacts,

$k_{6\text{-}3}$ – biological impacts.

The impact of biological factors on the lifespan of a composite insulation system (ETICS) is not negligible and can be determined if we presume that all the other factors impact the durability in a positive way. That means these factors have a value of 1.00. The final constant is then calculated as:

$$K = k_6 = \frac{k_{6\text{-}1} + k_{6\text{-}2} + k_{6\text{-}3}}{3} \tag{4}$$

and the actual determined lifespan of a composite insulation system with probable or already existing biocorrosion is calculated as:

$$Z_S = \frac{k_{6\text{-}1} + k_{6\text{-}2} + k_{6\text{-}3}}{3} Z_Z \tag{5}$$

If we take the final constant of the facts influencing the lifespan to be at a “very aggressive” level (i.e. $k_{6\text{-}3} = 0.71$ according to Table 1) because of biological factors, then:

$$K = (1 + 1 + 0.71) /3 = 0.9033$$

and the basic lifespan of composite insulation systems is considered to be (Šternová Z., et. al. 2002) approximately:

$$Z_Z = 25 – 35 \text{ years},$$

whereas the limiting factor is the final layer – thin plaster – the actual lifespan of a composite insulation system with biocorrosion falls within the interval:

$$Z_S = < 22; 31 > \text{ years}$$

In reality, it is impossible to only encounter one single factor that will impact the lifespan of ETICS. Other negatives such as the project, the technology of the execution or the method of operation, can further decrease the expected lifespan. In extreme conditions involving these factors, it is possible that the expected lifespan can reach only half of these values or that the whole system will collapse.

## 2.2 Experiment – empirical findings about the periodicity of maintenance

For the public and also some experts, the biocorrosion on external walls with ETICS is just a visual problem, because they believe that the functioning and effectiveness of the external walls to protect against weather phenomena is not decreased. However, the presence of algae increases humidity in its surroundings and thereby creates suitable microclimate conditions for other organisms, e.g., bacteria, moss and higher organisms. This co-existence of all these microorganisms influences the expected functionability, reliability, and, therefore, the durability of insulation systems.

It is possible to increase or maintain the original expected lifespan of a building through maintenance, whether in the form of prevention or in the form of repairs (Somorová, V., 2007). Every change (and especially any decrease) in durability forces the investor or owner to consider the need to properly maintain the building.

The generalisation of the results according to (Antošová, N. 2007) and (Božík, M., Antošová, N., 2004) has shown and proven that:

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- Microbiological substances appear on a wall with a composite insulation system for the first time after about 5 to 7 years of its implementation. This occurrence is closely related to various factors, including the effectiveness of the chemical substances added to liquid plasters, which affect the microorganisms in a toxic way.
- The existence of biocorrosion is influenced by suitable environmental conditions and the physical and chemical characteristics of the surface (orientation towards cardinal points, temperature, humidity of the surface, and the air, nutrition, light, chemicals, etc.)
- The best results with sanitation technology and the prevention of biocorrosion were achieved by a direct chemical method in combination with a mechanical intervention. The chemical method involves the removal and destruction of the microflora – killing the cells or removing the live parts, including the organic elements.
- The best time for the application of a chemical method is at the beginning of the development of the algae, i.e., during the autumn or spring. In relation to the technology, application with a roller during dry and wind-free weather has proven to be the best.
- It is required by legislation that algaecide products affect the environment in the least possible way; therefore, their long-term effect is questionable (their effectiveness in relation to the chemical composition of the product, its concentration, its lifespan and UV light, is usually only 2 to 5 years).
- The growth and vegetation of algae is renewed after a period of time on the surface of a wall. This is caused by the current environmental conditions (humidity, cleanliness of the air, dust), by the construction on previously unoccupied sites and by the creation of new conditions in already built-up areas.

Therefore, to eliminate algae on an external wall with a composite insulation system, a periodic preventative measure is needed – maintenance by decontamination and cleaning, and intervention to prevent the long-term effects of humidity.

The periodicity of maintenance is closely connected to the exact determination of the durability and deterioration of a construction or a building.

The periodicity of the maintenance of a composite insulation system is determined by the lifespan of the limiting element (plaster) or the durability of the protection of that element (e.g., hydrophobing, decontamination, prevention with biocide products).

The cycle of maintenance (prevention and protection) of the top layer of ETICS against adverse biological influences is closely connected with the effectiveness and lifespan of the chemicals in the product used for decontamination or prevention, according to empirical studies.

Technologies for the decontamination of ETICS with biocorrosion were experimentally tested in 2005. The effects of several freely available products on the market were observed, together with the amount of biological materials on the wall before and after the application of the biocide (during various time periods).

The results were satisfactory and clearly show the importance of maintenance. They present the issue of the periodicity of maintenance. The biological materials were decreased or even destroyed by the decontamination, depending on the type of product used and its lifespan. The timing of any new increases in biological materials on the surface of an ETICS was largely influenced by the surroundings, when only parts of the whole wall were chosen for the experiment. The surrounding parts of the wall were left in their original state. Therefore, the effectiveness of the

**Fig. 1** *Records of decontamination experiment on ETICS in 2005. Record created 7 days after the application of six different products. Noted decrease of new microorganisms, e.g., in Squares No. 1 and 2 (from the left) to half the amount (Antošová, N., 2007).*

**Fig. 2** *Records of decontamination experiment on ETICS in 2006. Noted increase of new microorganisms, e.g., in Square No. 6 (from the left). Sample No. 1- destruction of microorganisms outside the designated area (Antošová, N., 2007).*

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**Tab. 2** *List of biocide products applied (author´s experiment).*

| Sample number | Description by manufacturer |
|---|---|
| 1 | Fungicide and insecticide concentrate. Borite acid 9%, Alkylbenzyl- dimetylamonium chloride min. 9%. Application by brush, repeatedly. |
| 2 | Removing green surface and moss. Didecil (dimethyl) Amonium chloride. Application by brush. |
| 3 | Effective on fungi.  47.2 g/l Sodium hypochloride. Application by spray. |
| 4 | Insecticide, poisonous for water plants, effective with parasitic insects. Cypermetrin 0.05%. Application by spray. |
| 5 | Colourless fungicide solution. Karbendazim 0.63% and isotiasolon binder 0.22%. Application by brush, repeatedly. |
| 6 | Anti-mould paint. Application by brush. |

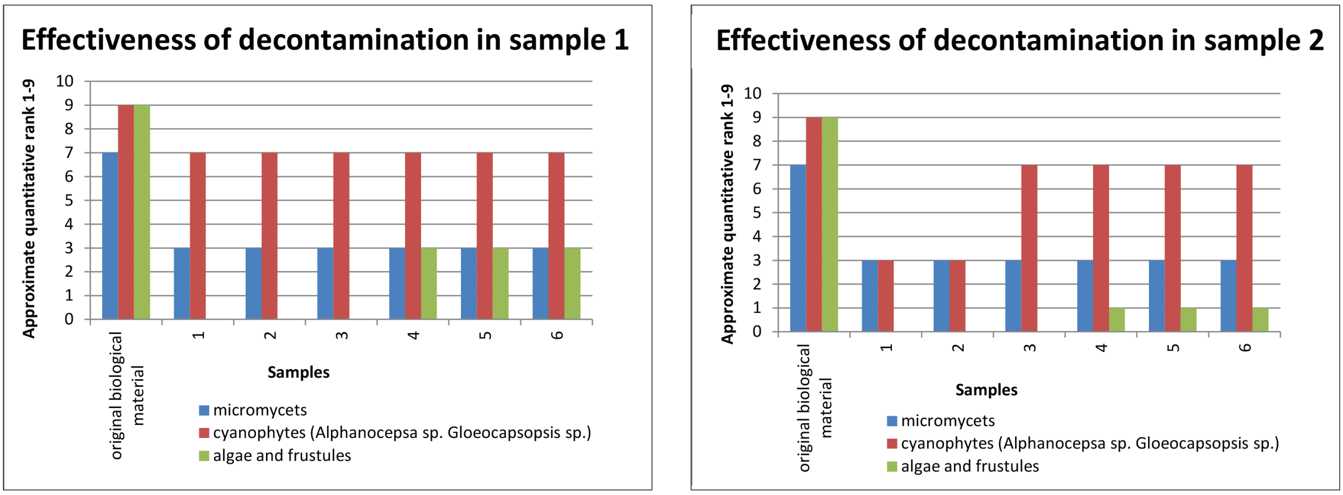


**Fig. 3** *Graphic representation of the effectiveness of biocide products when decontaminating an ETICS (results of experiment, samples taken 1-7 days after the application of biocides, samples taken 2-21 after the application of biocides, results of the author´s experiment).*

product used is adversely affected by the surrounding parts of the wall, because algae and microorganisms developed quickly onto the tested parts.

If we consider the samples with a biocide of the best quantitative results in the destruction of biological materials on the top layer and its ability to destroy them after 4 years outside the designated area (Fig. 4), it is possible to consider maintenance every 5 to 7 years as the best option.

In 2011, the decontamination experiment was repeated on the ETICS with biocorrosion. The same chemical product dissolved in water  and based on ammonia and aldehydes was used on two samples of ETICS. The difference was in the application technology. On the first sample, washing with high-pressure water was used after 24 hours; the second sample was not further treated. The samples were in the size of 120 x 80 cm. The lifespan of the chemical product was the same in this case. The surrounding areas of the sample were left untreated and with the original microorganisms.

**Fig. 4** *Records of the decontamination experiment on ETICS in 2009. Note the increase in new microorganisms except in Square No. 1 (from the left). Sample No. 1- destruction of microorganisms outside the designated area (Picture from the archives of the author´s experiment).*

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**Fig. 5** *Records of the decontamination experiment on ETICS in 2011. The state before the application – outlining the area. Cleaning with high-pressure water after 24 hours. (Picture from the archives of the author´s experiment).*

**Fig. 6** *Records of the decontamination experiment on ETICS. State of the sample in January 2012; this sample was not washed with water after the application of a biocide. (Picture from the archives of the author´s experiment)*

**Fig. 7** *Records of the decontamination experiment on the ETICS. State of the sample in January 2012; this sample was washed with water after the application of a biocide. (Picture from the archives of the author´s experiment)*

**Fig. 8** *Records of the decontamination experiment on the ETICS. State of the unwashed sample from Fig. 6, now in January 2013. (Picture from the archives of the author´s experiment).*

**Fig. 9** *Records of the decontamination experiment on the ETICS. State of the washed sample from Fig. 7, now in January 2013. (Picture from the archives of the author´s experiment).*

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The results of the experiment were than less satisfactory. The first sample without washing showed the black marks of biological material after 2 years. The activity of the microorganisms was not observed. It is clearly visible with the naked eye that both samples of the ETICS were colonised by microorganisms after 3 years. The results were influenced by the chemical composition of the product used (low impact on the environment, dissolvable in water, low risk of soil contamination). The results show the importance of further maintenance after the application of the product to prolong the lifespan. The results also offer a comparison of the periodicity of maintenance with or without using high-pressure water. The microbiological results of effectively destroying the microorganisms have not yet been analysed.

## 3. RESULTS AND CONCLUSION

The life cycle of a construction includes preparation, execution, period of usage and liquidation. All the phases of a life cycle present a financial burden. It is possible to lower the expenses during the period of usage with maintenance (Somorová, V., 2007).

The importance of the maintenance of composite insulation systems with biocorrosion is not negligible. An extensive technological intervention, which should return to the construction its expected characteristics and which is undertaken within the presumed lifespan of the building, leads to unexpected financial burdens on the investor, a decrease in the effectiveness of the insulation and also a decrease in the return on the investment.

Colonisation of external walls by microorganisms is, according to the mathematical model presented, a factor decreasing the basic lifespan of an ETICS by 3-4 years. In extreme conditions, when taking into account the project, its execution and its maintenance and usage, the lifespan can reach only half of its predicted value.

It is necessary to use a biocide product with a low level of adverse impact on people, animals and the environment when decontaminating and destroying microorganisms. The products should be dissolvable in water, without the possibility of damaging the environment. According to experiments, the treatment of an external wall with ETICS causes the decontamination to last for 3 to 6 years. This shows the durability of the decontamination; therefore, the periodicity of the maintenance and protection should be between 3 and 6 years. The exact interval depends on the monitoring and controlling of the ETICS and on the technical state of the ETICS. A better resistance of an ETICS against microorganisms cannot be achieved without maintenance and the repair of tears and mechanical defects.

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