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The role of fungi in biodeterioration of sandstone with reference to Mahadev temple, Bastar, Chhatisgarh

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Abstract
Fungal ability in production of pigments and organic acids have crucial role in discoloration and degradation of different types of stone in cultural heritage objects. Additionally, stone objects may support novel communities of microorganisms that are active in biodeterioration process. This investigation focuses on mycological analysis of microbial biofilm from Mahadev temple, made of sandstone, and which was heavily colonized by fungi. The 22 fungal flora including filamentous micro fungi with specific distribution on sandstone substrate was isolated. During the investigation period it was observed that Aspergillus Scalrotium was found as dominant. The identified micro fungi cause discoloration, as well as mechanical exfoliation of building stone material that was analyzed through mechanical hyphae penetration and production of dark pigments and organic acids.

Keywords: biodegradation, cultural heritage, fungi, micro-organism, biodeterioration.

INTRODUCTION

Chhattisgarh is the land of ancient culture which has lots of ancient monuments, temples and fort etc. & Mahadev temple of the Bastar district of this state is located in highly naxal effected small village which is 20 kms far away from the district head quarter Jagdalpur across the Indravati River built around the 11th century, it was also believed that this is the capital of the Kalachuris for a short period of time. There is an interesting Shiva (Mahadev) temple in the village, dated to the same period. It contains several sculptures, including an image of Mahisasurmardini, excuted in folk style and a dancing Chamunda Devi, smeared with vermilion(1).

The patches on this monument pertain to fungi that are part of the total vegetational growth over their surface.

Fig1. Google map located of Mahadev temple

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Every nook and corner of Chhattisgarh has traditional heritage. Numerous factors affect the stone durability. Stone surfaces are continuously exposed to physical, chemical and biological degradation. Physical, chemical, and biological agents act in co-association, ranging from synergistic to antagonistic, to the deterioration. Among biological agents microorganisms have critical importance, in stone deterioration (2). They can cause various damages on the stone surface, suchas: formation of biofilm, chemical reactions with substrate, physical penetration into the substrate as well as pigments production. Fungal ability in production of pigments and organic acids have crucial role in discoloration and degradation of monuments (3).

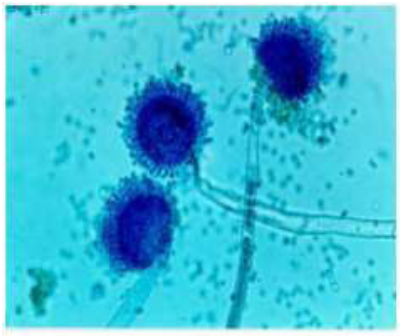
Fig 2. Mahadev temple, Bastar (Before conservation)

MATERIAL AND METHODS

Sampling and Isolation of fungi

Samples of historical stone monument were collected from various places of the surface of the said temple. After a careful observation visible alterations and degradation was mapped and

after that the samples was taken for mycological analyses by swabbing surfaces with sterile cotton swabs. The samples was then stored at 4°C.During the investigation period PDA *Cultural* media was used for the isolation of microorganisms. Few drops of sample pour in the petridishes and kept this petridishes at 28±1°C for 7 days for incubation (4**).** At the end of incubation period fungal colonies were counted, isolated and identified with the help of available literature and finally send this culture to authentic authority: National center of fungal taxonomy, Delhi for identification. During the investigation period maximum percentage contribution showed by *Aspergillus Scalrotium* (12.35%) followed by *Aspergillus niger* (10.58%), and Aspergillus *fumigates* (10%). While minimum percentage contributions (0.58%) were observed for *Arcemonium scatrotium* and for *Paecilomyces varioti*.



Aspergillus niger

Fig 3.Fungal species on Mahadev temple

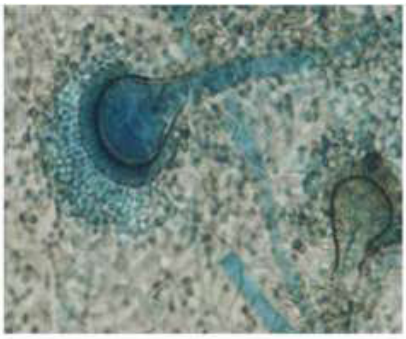
Deterioration process

The acids produced by various species of fungi function as chelating agents that can leach metallic cations, such as calcium, iron, or magnesium, from the stone surface . Oxalic acid can cause extensive corrosion of primary minerals and the complete dissolution of ferruginous minerals through the formation of iron oxalates and silica gels. Laboratory experiments have demonstrated that basic rocks are more susceptible to fungal attack than acidic rocks. It has also been shown in the laboratory that fungal species such as Aspergillus niger were able to solubilize powdered stone and chelate various minerals in a rich glucose medium because they produce organic acids such as gluconic, citric, and oxalic acids (5). Similar experiments involving stone have demonstrated the formation of oxalate crystals, which adhered to lichen and fungal hyphae or were deposited nearby.

Fig 4. Mahadev temple, Bastar (During conservation)

Removal of dust and dirt

The steps taken by Archaeological Survey of India for the removal of dust and dirt accretion upkeep of stones in neutral pH by soft brushing. The fungus was removed by applying 2-3% solution of ammonia in water and scrubbing with nylon brush. Black patches appeared after removal of thick layer microorganism which was washed out with the help of dilute solution of oxalic acid in water. A dilute solution of a non ionic detergent with liquid ammonia was applied on treated surface to remove dirt, dust and little amount of acid and ammonia if remained on the surface during the chemical treatment. Lime wash, red ocher and iron oxide accretion were removed using dilute (10-15%) aqueous acetic acid and oxalic acid solution as per the suitability and afterwards neutralized using aqueous ammonium hydroxide solution.



Aspergillus fumigatus

Fig 5. Fungal species on Mahadev temple

Biocidal treatment

Biocides refer collectively to bactericides, fungicides, algicides, and herbicides. They are frequently used to eliminate and inhibit biological growth. Several studies exist on the effect of biocides on the activity and growth of microorganisms on stone in tropical regions (6). Biocides may inhibit the metabolic activity of target organisms, thereby causing irreparable damage and even death. Numerous studies have tested the effects of biocides on microbial growth on stone. Several authors have developed laboratory testing methods that evaluate the effectiveness of biocides on different organisms and stone surfaces. 2% aq. Solution of sodium pentachlorophenate was applied on clean dried surface for arrest further micro vegetation growth on said monument (7).

Fig 6. Mahadev temple, Bastar (During conservation)

Biocide Application: Procedures and Precautions

Biocides may be washed out by rain before they have had time to act. Biocidal treatments should therefore be undertaken during dry conditions. Windy weather may lead to excessive drift of biocidal spray and pose health and environmental hazards. The solution of an appropriately chosen biocide must then be carefully prepared and applied in strict accordance with the manufacturer's recommendations for safety and protection of operator and the environment. When handling and mixing biocides, one must remember to always wear rubber gloves, safety glasses, and a respirator. Only the required quantities of diluted biocides should be prepared, as their effectiveness may be reduced when they are stored for a long time (8). Depending on the state of conservation of the stone, the organisms to be eliminated, the density and diffusion of biological attack and product chosen, treatments may be carried out by spraying, brushing, applying poultices, or injection. Worldwide spraying and brushing of diluted biocidal solutions appear to be the most common modes of application. Brushing is recommended when the stone surface is in fairly good condition and the area required to be treated is relatively small. Spraying is the preferred choice for deteriorated stone surfaces.

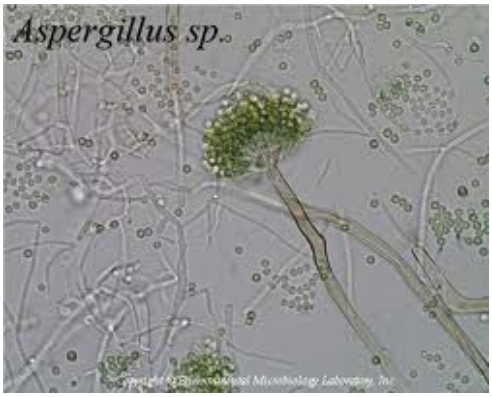


Fig 7. Fungal species on Mahadev temple

Some Considerations in Biocide Selection

While the term biocide pertains to any chemical able to kill or inhibit the growth of living organisms, it is most commonly used with regard to microorganisms and higher plants. These chemicals, however, are also potentially harmful to wildlife and humans. For this reason, there is a mandatory need to identify and disclose the toxicological properties of biocides and to perform a risk assessment for each specific biocide application. When considering biocides for controlling and eradicating biological growth on stone monuments, several factors, such as efficiency against target organisms, resistance of target organisms, toxicity to humans, risks of environmental pollution, compatibility with stone, and effects of interactions with other chemical conservation treatments, need to be discussed . Biocide efficiency generally refers to its ability to effectively kill or inhibit growth of target organisms. The first step in choosing a biocide for stone should be to identify the biodeteriorating agents as accurately as possible. Often biocides tend to be more efficient on some organisms than others. Efficiency depends on the type of biocide and the conditions under which it is applied. Parameters such as temperature, rainfall, pH, relationship between concentration and activity, and contaminants, which determine the effectiveness of a biocide, must be carefully considered. Biocides with a wide spectrum of action against most target organisms and persistent activity seem most suitable for inhibiting organism colonization (9).

RESULT AND DISCUSSION

Current strategies to reduce biodeterioration and repair damage that has already occurred are discussed. The study of biodeterioration of stone cultural heritage materials is as diverse as the sites studied. The biodeterioration of ancient buildings and monuments depend upon many factors which includes environmental factors like light, moistures, weather, temperature etc. Type of micro organism that is its potential towards the colonization in the surrounding environments, materials of the monuments etc. all these equally contribute the biodeterioration of any monuments (10). Seasonal variation affects Aeromycoflora of the area. Fungal spores are not equally distributed in the environment their distribution varies according to geographical location and meteorological conditions. During the investigation period, it is also observed that the maximum fungal species are recorded in winter season, moderate fungal species in rainy season and minimum fungal species are recorded in summer season. During the period of investigation, overall 22 fungal species (168 fungal colonies) belonging to 16 genera of fungi were observed from Mahadev temple. Out of 22 fungal species, maximum number of species observed from Anamorphic group. The identified microfungi cause discoloration, as well as mechanical exfoliation of building stone material that was analyzed through mechanical hyphae penetration and production of different pigments (*Aureobasidium, Cladosporium, Alternaria*) and organic acids (some species of genus *Aspergillus*, *Alternaria, Penicillium*). *Aspergillus species* were among dominant microfungi on the mineral substrate (11).

Fig 8. Mahadev temple, Bastar(after conservation)

CONCLUSION

To conserve these monuments scientific treatment is very essential. But it is more essential that the identification of problem and selection of chemical should be accordance the problem of stone surface. Biological infections and the intensity of biodeterioration processes are strongly influenced by water availability. The establishment of fungi on rocks is possible even without the pioneering participation of phototrophic organisms. Fungi are especially concentrated in stone crusts. They are able to penetrate into the rock material by hyphal growth and bio corrosive activity, due to excretion of organic acids or by oxidation of mineral

forming cations, preferably iron and manganese. Their deterioration activities also include discoloration of stone surface, due to the excretion of melanin by dematiaceus fungi (12). Recently, it has been apparent that fungi comprise a significant component of micro biota in a wide range of rocks including sandstone, granite, limestone, marble and gypsum. The reported presence of 22 different microfungi on stone in hypogean cemetery in temple. In the Earth's lithosphere, fungi are of fundamental importance as decomposer organisms, being ubiquitous in subaerial and subsoil environments. The ability of fungi to interact with minerals, metals, metalloids and organic compounds through biomechanical and biochemical processes, makes them ideally suited as biological weathering agents of rock and building stone (13). Biological and mycological investigations are very important part of good conservation and cannot be ignored in modern conservation concept which includes close collaboration between art and science. Regular cleanliness and proper use of fungicide can control the biodeterioration of monuments.

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