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THE ROLE OF FUNGI IN DEGRADATION AND DETERIORATION OF MONUMENTS: MAHADEV AND SURYA TEMPLES IN NARAYANPUR, INDIA

Sanjay Prasad GUPTA*

Archaeological Survey of India, Raipur Circle, Raipur, Chhatisgarh, India

Abstract

Thirteen species of fungi were obtained out of ten samples (five samples of each monument) collected from various places of stone structures of the monuments. Aspergillus fumigatus Fr.species are found in all samples and their percentage frequency is very high. Aspergillus fumigatus Fr., Aspergillus terreus Thom. And Aspergillus flavus fungal species are common on stone of the monument. There should be given priority to the characteristic features of stone structures, their different forms, designs and materials in finding the cause(s) of their degradation and deterioration) This study infers that in the degradation and deterioration of stone there is equal contribution by microbes and the design of stone structures. Hence the nature of the substrate, the relation between substrate and organism, the relation between the design and growth of organism, their frequency distribution are essential components in stone monument preservation interventions.

Keywords: *microorganism; biodeterioration; biodegradation; conservation state; preservation; biofilm; pigment.*

Introduction

The little village of Narayanpur, 130 kms from Raipur (capital of Chhattisgarh State) of India is known for its beautiful Shiva Temple (Fig. 1). This east facing temple dedicated to lord Shiva consists of a Garbhagriha and a pillared mandapa. The temple is embellished with the sculptures of gods and goddesses as well as secular themes including erotic figures. It dates from the 13th -14th century AD and one other west facing small temple with a curvilinear sikhara standing on a platform is dedicated to Aditya or Surya. It is devoid of ornamentation and ascribable from the 9th century AD [1]. Both temples were built by the rulers of the Haihaya dynasty. In a small clearing behind the temple, a number of sculptures and artifacts excavated from the site by the department of Archaeological Survey of India have been displayed. These figures which include Buddha's bust, Nataraja, Vishnu and other deities bear testimony to the fact that there might indeed have been the fabled garden landscaped with lakes and sculptures to welcome weary pilgrims [2].

In recent decades the rate of stone decay in monuments has undergone dramatic acceleration due to environmental adverse impacts. Stone monuments with direct exposure to environmental conditions are affected not only by physical and chemical weathering but also by

* Corresponding author: guptasanjayprasad@gmail.com

biological activities of stone dwelling micro organisms among which algae, fungi and bacteria often prevail.

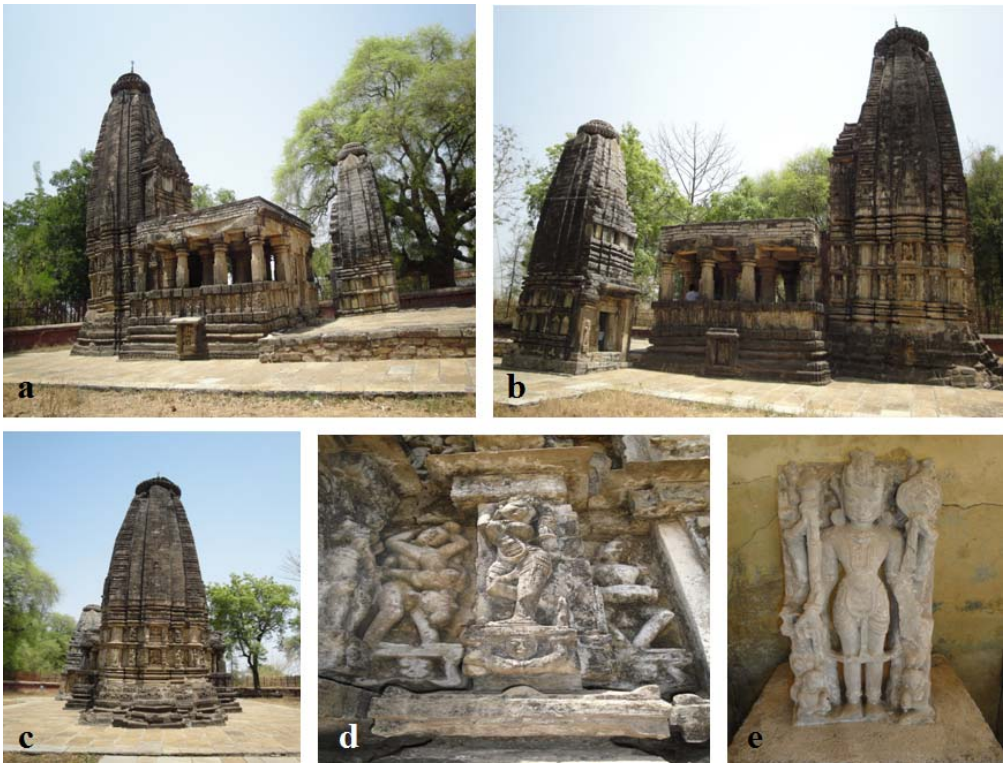

Fig. 1. View of the monuments and structures: a - front view showing Mahadev and Surya temple; b - lateral view showing Mahadev and Surya temple; c - lateral view showing Mahadev temple; d - sculpture of stone structure; e - excavated sculpture in the campus of the temples

Eckhardt (1978, 1988) reported that fungi should be associated with the degradation and deterioration of stone [3, 4]. The mechanism of fungal penetration was reported to be both mechanical and chemical as a result of acid secretion. However the community composition is subject to change based not only on season but also on the design, structural components and substrate of the monument. One of the consequences of the microbial development is the formation of a pigmented biofilm that covers the sculpture and other stone structures. It is evident that the characteristics and distribution of microbial communities is dependent upon the stone design, degree of shading, moisture and temp rather than the nature of the surface of different kinds of molding or components in the basement [5-7]. Hence the relation between the stone design, composition and growth of the organisms, their frequency distribution in addition to the effect of climatic conditions are essential in planning of the stone monument preservation and restoration.

Materials and methods

Study sites

The stone monuments selected for sampling are the Shiva temple and Surya temple both in Narayanpur village and inside 2km from Sirpue - Kasdol main road of Balodabazar district of Chhattisgarh state. Totally 10 sample (05 sample of each monument) were collected from

various places of the surface of monuments and were brought to the laboratory under aseptic conditions.

Isolation of fungi

The isolation of micro-organisms was done by culturing the samples and by direct incubation of samples in moist chamber. During the investigation period PDA media was used for the isolation of microorganisms. There were poured some drops in the Petri dishes and were kept at 28±1°C for 7 days for incubation [8]. At the end of incubation period fungal colonies were counted, isolated and identified with the help of available literature and calculated their frequency. Some species are identified as common in both temples (Table 1). The fungal species are showing in table 2 and 3 and also as a graph in figures 2 and 3.

Percentage of frequency

Frequency occurrence was calculated as follows ***Percent of frequency = Number of samples in which specific organism occurred/Total number of samples examined***

Based on the frequency occurrence the algae and fungi were grouped as Rare (0-25% frequency), Occasional (26-50% frequency), Frequent (51-75% frequency), and Common (76-100% frequency) species.

Table 1. Occurrence, percentage frequency and frequency class of different fungal species in two stone monument sites

Fungal species	Shiva temple	Surya temple	Frequency (100)	Class Frequency
Aspergillus fumigatus Fr.	+	+	100	C
Aspergillus terreus Thom.	+	+	100	C
Aspergillus flavus	+	+	100	C

(+) = presence of species; (-) = absence of species; C = common; O = Occasional; F = frequent, R = rare

Table 2. Occurrence, percentage frequency and frequency class of different fungal species in Surya temple, Narayanpur

Fungal species	S1	S2	S3	S4	S5	Frequency (100)	Class Frequency
Aspergillus fumigatus Fr.	+	+	+	+	+	100	C
Aspergillus terreus Thom.	+	-	+	-	+	60	F
Aspergillus flavus	+	-	+	+	+	80	C
Aspergillus niger	+	+	-	-	+	60	F
Penicillium Sp.	-	+	+	-	-	40	O
Mucor sp.	-	+	-	-	-	20	R

(+) = presence of species; (-) = absence of species; C = common; O = Occasional; F = frequent, R = rare

Table 3. Occurrence, percentage frequency and frequency class of different fungal species in Mahadev temple, Narayanpur

Fungal species	S1	S2	S3	S4	S5	Frequency (%)	Class Frequency
Aspergillus fumigatus Fr.	+	+	+	+	+	100	C
Aspergillus terreus Thom.	+	-	+	-	+	60	F
Aspergillus flavus	+	-	+	-	-	40	O
Cladosporium	+	-	-	-	+	40	O
Rhizopus stolonifer (Ehrenb ex Fr.) Linder.	+	+	+	-	+	80	C
Curvularia sp.	+	-	+	+	+	80	C
Unidentified rounded spores	+	-	+	+	+	80	C

(+) = presence of species; (-) = absence of species; C = common; O = Occasional; F = frequent, R = rare

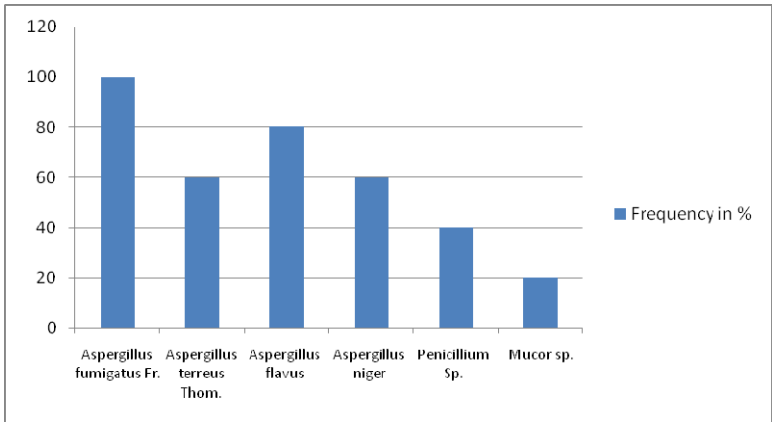

Fig. 2. The frequency of fungal species in Surya temple at Narayanpur

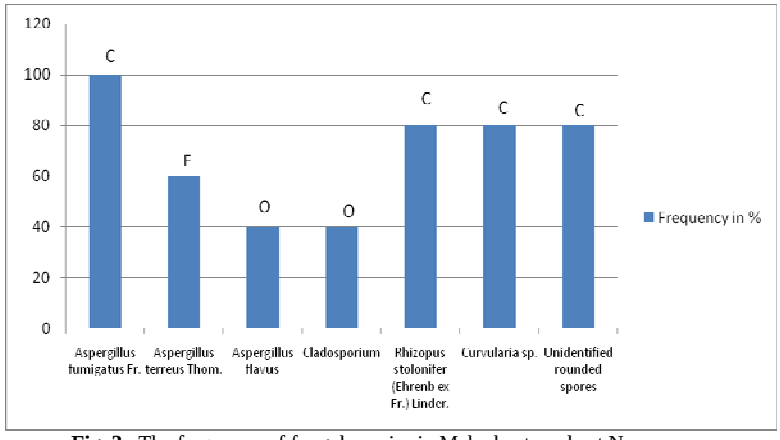

Fig. 3. The frequency of fungal species in Mahadev temple at Narayanpur

Results and discussions

Thirteen species of fungi were detected in the samples collected from both the monuments (Table 2 and 3). Fungal species were found in the various locations of the stone surface in a biofilm where their effect on the stone substrate led to the degradation and deterioration of the monument. These communities forming thick biofilms produced intense pigmentation varying from dark green to dark red which altered the aesthetic appearance of the stone (Fig 1). *Aspergillus fumigatus Fr*., *Aspergillus terreus Thom*. and *Aspergillus flavus* fungal species are common on stone in the monument. There is not much variation in the fungal species identified in these two monuments. The presence of fungal species and their percentage of frequency and frequency class are depicted in Table 2 and 3. The number of microorganisms increased from late pre-monsoon to monsoon. In summer they turned as dry black biomass but become abundant once again with rains. Hence if this dry biomass could be removed systematically before monsoon, then their growth could be minimized.

Conclusions

Climatic factors on rock and stone monuments in dry areas may not favor the growth of lichens but allow the colonization of fungi. The substrate features and environmental conditions

suitable for algae are also suitable for fungi except that they need additionally some organic nutrients and perhaps the initial algal growth and decay of stone to some extent helps/aids in the successive growth of fungi [9]. Air borne fungi fail to settle on polished surfaces but the fungal hyphae can easily penetrate the porous and rough surfaces of the stone monuments. Though crevices are the favored places, under optimal environmental conditions they colonize the entire surface as seen in monument (Fig. 1). Through electron microscopy found fungi in association with bacteria widespread in degradating and deteriorating stone [10]. Earlier researcher reported that fungus first settles on the weakest zone of the stone surface whereby stating that bio-receptivity is the essential prerequisite of the stone to be colonized [11]. In penetration phase fungus extends its hyphae into the inner part of the stone and establish as larger colonies. Earlier researcher [4] have reported that the design of buildings give some implications on the weathering of the surfaces and that the attack by microbes follows the initial physical and chemical weathering and that weathering is more rapid when microbes are involved. Hence the studies of distribution patterns and colonization patterns are essential in formulating preservation and conservation works. The characterization of these microorganisms and a clear understanding of their role in the process of stone decay are essential for suitable restoration interventions.

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