Abstract of Thesis

Biodeterioration of Selected Historical Monuments by Lower Plants and Cyanobacteria

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Introduction

Biodeterioration is the undesirable changes in the properties or quality of a material or a structure by the vital activities of organism. It occurs on humid and exposed substrates such as buildings, structures and historical monument walls. It is caused by several groups of biological organisms. Among groups of biological organisms, cyanobacteria, some green algae and lichens are pioneer organisms to colonize and deteriorate the structure. Followed by bryophytes and some allied vascular plants forming a seral community and ultimately leading to a climax community. Hence, it is very important to stop the growth of the biological organisms in the initial phase resulting in better conservation of the monuments or structures. The current study focuses on four groups of organisms named cyanobacteria, micro green algae, bryophytes and lichens on selected monuments in Gujarat which have social, cultural and heritage importance. The current study was carried out on six monuments of Champaner Pavagadh and two cites from the campus of the M. S. University of Baroda.

Gujarat is rich in its culture heritage and monuments. All these monuments are in different phases of conservation. Some monuments are degraded while some others have been restored and are in a good state of preservation. Degradation of the monument caused by the activity of biological organisms invading on the structure as well as anthropogenic activity. At some places ruined monuments was restored by normal method of plugging out the plants. Very few monuments have been restored employing scientific approach using chemical treatment for conservation and preservation of the monuments. For scientific approach, needs to study the diversity of organisms and their mechanisms by which they causing the biodeterioration of the monuments.

With an aim to ensure the effective conservation of important monuments, this study has been proposed with the following objectives,

1. Identification of the diversity of biofouling lower plants and cyanobacteria at the selected site using morpho-taxonomic as well as modern methods.
2. Analyzing the specificity of biofoulants for specific geological substrates.
3. To study the specific role of different biofoulants on the process of biodeterioration.
4. To suggest measures for the control of these biodeteriogens.

To achieve above mentioned objectives, selected sites were visited. The biofilms, bryophytes, lichens and substrates specimens were collected from the selected locations. The biofilm samples were cultured and identified by molecular method and their sequences were submitted in GenBank NCBI database. Bryophytes and lichens were identified based on the key characters from the standard floras. Specificity of biofoulants with specific substrates were studied. Collected rock samples were analyzed by microscopic analysis of the thin section of the substrate samples and powder XRD analysis. All groups of organisms played different role in the mechanisms of biodeterioration due to their different physiology. Hence, in cyanobacteria, exopolysaccharide was extracted and characterized by HPTLC method. Bryophytes role in biodeterioration was studied by calcium uptake analysis. Lichens have secondary metabolite and acids play role for biodeterioration. In the current study, chemical spot test and literature survey was used for knowing the presence of the secondary metabolites or acids. For devising measures for the control of biodeteriogens, *in vivo* experiment was conducted on one of the selected site of the MSU campus.

Results and Discussion

A total of 36 species of biofoulants have been identified from the selected monuments sites. Five species of cyanobacteria, one of microalga, seventeen species of bryophytes and eight species of lichens were identified to be growing on the selected monuments of the Champaner-Pavagadh complex. Among them eight species of cyanobacteria and two species of bryophytes were observed on the selected monuments of MSU campus. On the building of the MSU campus, among the cyanobacteria members of the order Chroococcales and among bryophytes, members of Pottiales were dominant. The dominant members at the Champaner-Pavagadh complex among the cyanobacteria were members of Synechococcales and Nostocales while members of Marchantiales and Pottiales were dominant among the bryophytes. Among the lichens identified, the crustose lichens were dominant and while one member each of foliose and squamulose-foliose lichen was also noticed.

All biofoulants were recorded from different geological substrata such as brick, stone, lime coating surface and mortar. Majority of the cyanobacteria were isolated from lime coating surface and mortar, while bryophytes from mortar and brick surfaces. All observed lichens were saxicolous because they were all found growing on stone. The characterization of geological substratum, mainly revealed the presence of calcareous materials (primary silica and secondary silica), ferruginous materials and feldspar in thin section and powder X-Ray

Diffraction (XRD) analysis. Based on these study, no specific correlation of species with substratum was recorded. Some species were recorded on more than one substratum while some were found on single substratum only.

Each group of organism has a different role in deterioration. The cyanobacteria secrete polysaccharides either into the external environment or synthesize them extracellularly by cell wall-anchored enzymes and these are referred to as exopolysaccharides. Exopolysaccharide are complex in nature and have the ability to enhance the aggregation of soil particles, prevent desiccation and facilitate trapping of nutrients. This resulted in the formation of biofilms which facilitates the colonization by other plant groups. This results in the discoloration and deterioration of the monuments. To understand the composition of the exopolysaccharides, characterization of EPS of five species of cyanobacteria (*Chroococcidiopsis cubana, Desmonostoc muscorum, Nostoc punctiforme, Leptolyngbya foveolarum, Leptolyngbya crispata*) and one species of microalga (*Asterarcys quadricellulare*) were done by High Performance Thin Later Chromatography (HPTLC) method. Each isolated strains of cyanobacteria and microalga revealed the presence of three to five monosaccharides as observed by HPTLC fingerprint profile. In bryophytes, cell wall has a role for uptake of some nutrients and non-essential cations because fixed negative charge sites were present on it. Selected monuments having utmost calcareous material. Calcium which is the major exchangeable cation component from the monument substratum. Such cations easily diffuse through the apoplast regions and are also readily accumulated in this region and can be analysed for cation uptake. Calcium uptake was studied in the commonly found bryophyte species. The uptake was compared between one moss, *Hyophila involuta* and one liverwort, *Asterella angusta*. Flame photometry revealed that *Asterella angusta* had a higher calcium uptake compared to *Hyophila involuta*. In lichen, several secondary metabolites including unique acids are responsible for deterioration of the monuments. Based on the chemical spot test on the field locations indicated the O-hydroxyl aromatic aldehydes and anthraquinone pigments present in *Caloplaca cupulifera* and *Caloplaca awasthii* respectively. The review of literature showed the occurrence of similar species as recorded species in the current study having three aromatic polyphenolic compounds and one aliphatic polyphenolic compound. These compounds caused damage the monuments by metal chelation and mineralization process.

Based on available literatures, an *in-vivo* experiment to test the efficacy of different control measures was devised. Two different chemicals were selected based on their physical

properties like colour, transparency and water repellent capacity after literature analysis and interaction with experts from the ASI. Both these chemicals are silane-siloxane based compounds. The experiment was demonstrated by five different treatments. All these different treatments have different outcomes. These different outcomes were compared based on the different criteria such as reappearance of biofilm growth, any additional biofilm patches observed as compare to the initial phase of treatments, size of the biofilm patches etc. Based on all these criteria, from all over the treatment, the treatment E gave the best results in each directions. Hence, it is proposed as the treatment of choice for monuments having similar substratum and environmental conditions.

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