

6.CONCLUSIONS

The objectives of the current study represented a challenging work with diverse taxonomic groups of photosynthetic organisms. They study with its interface in the field of archeology, botany, analytical chemistry, geology and microbiology and microbiology among others have attempted to work for the conservation of monuments which represent our rich cultural and academic heritage. The following are the major conclusions of the study:

- A total of 36 biofoulants belonging to different groups such as cyanobacteria, micro green algae, bryophytes and lichens were isolated from the selected monuments or buildings. Among them, the maximum number of biofoulants belonged to the bryophytes (17 species) followed by cyanobacteria (10 species), lichen (8 species) and micro green algae (1 species).
- Higher number of biofoulants were recorded from the selected monuments of Champaner Pavagadh (31 species) as compare to selected sites within the MSU campus (10 species). This difference is attributed to difference in location, surrounding diversity, elevation, anthropogenic activities and disturbance.
- From the monuments of Champaner Pavagadh 5 species of cyanobacteria, a single species of micro green alga, 8 species of lichens and 17 species of bryophytes found while 8 species of cyanobacteria and 2 species of bryophytes were isolated from the selected buildings of MSU campus. Lichens and micro green algae were not recorded from the selected buildings of MSU campus.
- Within the cyanobacterial group, *Chroococcidiopsis cubana* and *Leptolyngbya foveolarum* were dominant on the monuments of the Champaner Pavagadh (Saher ki Masjid and Mandavi) and MSU campus (Arts dome). Other predominant organisms *Nostoc punctiforme* (Makai Kothar and Navlakha Kothar) and *Desmonostoc muscorum* (Amir Manzil and MSU campus - Arts Dome) were observed from the specific selected sites.
- Among the bryophytes, the moss, *Hyophila involuta* (Saher ki Masjid, Mandavi, Amir Manzil, Makai Kothar and Navlakha Kothar) and the liverworts *Asterella angusta* (Makai Kothar and Navlakha Kothar), *Riccia billardieri* (Mandavi and Navlakha Kothar) and *Plagiochasma appendiculatum* (Makai Kothar and Navlakha Kothar) of dominant on the monuments of the Champaner Pavagadh. While *Gymnostomiella*

vernica found dominant on the selected sites (D. N. Hall and Arts dome) of the MSU campus.

- The genera *Caloplaca* and *Phaeophyscia hispidula* were the commonly found lichen on the Makai Kothar, Navlakha Kothar and premises of Jain temple. Lichens were not observed on the monuments of Champaner at the foot hill of Pavagadh and MSU buildings. The more natural surroundings, less pollutions and high elevation are the probable reasons why lichens were found on the monuments of Pavagadh hill only.
- The overall minerals study of the collected rock samples from or in an around the sites viz. Makai Kothar, Navlakha Kothar, Jain temple and antiquity from surrounding the Jain temple revealed the presence of primary and secondary silica, calcareous material, ferruginous materials, muscovite, aluminosilicate, hematite, magnetite, orthoclase and plagioclase feldspar.
- Among all these minerals, calcareous materials and calcite were most commonly occurring minerals as they were present in the building materials of all the sites analyzed.
- Based on geological investigation and the distribution of species, it was found that there was no specific correlation of species with substratum. Because some species were recorded on more than one substratum such as *Leptolyngbya* and *Nostoc* of cyanobacteria, *Hyophila*, *Asterella*, *Plagiochasma* and *Riccia* of bryophyte and *Caloplaca* and *Phaeophyscia* of lichen.
- Some were found on only a single substratum namely *Gloeocapsa*, *Gloeocapsopsis*, *Chroococcus* and *Aphanothece* of cyanobacteria, *Asterarcys* of micro green alga, *Anomobryum*, *Fissidens* and *Lejeunea* of bryophytes, *Lepraria*, *Endocarpon* and *Diploschistes* of lichen.
- The role of different species in biodeterioration was inspected in different groups using different techniques such as HPTLC analysis for EPS studies in cyanobacteria and micro green alga and flame photometry to analyse calcium uptake in bryophytes
- Analysis of EPS study revealed the presence of six neutral sugars like arabinose, galactose, glucose, fucose and xylose and one acidic sugar named uronic acid from the all the strains studied.
- Individually all strains examined showed the presence of three to five monosaccharides in current study. Glucose was present in all the studied strains while

Xylose was found only in one species *Leptolyngbya crispata*. Galactose found mostly in all strains except *Nostoc punctiforme*.

- The quantification study revealed that fucose was the predominant sugar as the covered percentage area in the strains *Desmonostoc muscorum* (48.37%), *Nostoc punctiforme* (51.09%) and *Asterarcys quadricellulare* (48.83). Followed by arabinose in the species *Leptolyngbya crispata* (35.85%), *Leptolyngbya foveolarum* (63.14%) and *Chroococcidiopsis cubana* (42.70%).
- Forbryophytes, calcium uptake was studied from the intercellular level of the plant cells. Because uptake chemicals are trapped in the apoplast region and further utilized for the plant growth.
- In current study, dominant species from the liverworts (*Asterella angusta*) and mosses (*Hyophila involuta*) were selected for the calcium uptake analysis by flame photo meter.
- The Calcium uptake analysis which was conducted only for the dominant liverwort and moss species revealed the maximum amount of calcium uptake from the liverwort – *Asterella angusta* was 52 µg/ mg of plant tissue while in the moss – *Hyophila involuta* had an uptake of 36 µg/ mg of leaf tissue. Based on this investigation, concluded that more calcium was absorbed by liverwort *Asterella angusta* than moss *Hyophila involuta*.
- In lichens, several secondary metabolites play main role in deterioration of the monuments. Hence, secondary metabolites were examined by chemical spot test and based on literature study.
- In chemical spot test, K⁺ purple and K⁺ red discovered in the *Caloplaca awasthii* and *Caloplaca cupulifera* respectively. These investigations suggested presence of O - hydroxyl aromatic aldehydes and anthraquinone pigment in *Caloplaca cupulifera* and *Caloplaca awasthii* respectively.
- Based on the examination, three aromatic polyphenolic compounds such as parietin from the species *Caloplaca*, atranorin and stictic acid from the *Lepraria lobificans* while one aliphatic polyphenolic compound zeorin containing in the *Lepraria lobificans* and *Phaeophyscia hispidula*.
- All these secondary metabolites having aromatic phenolic compounds, water soluble phenolic compounds and oxalic acids are believed to play an important role in the

deterioration of the monuments of Champaner Pavagadh by metal chelation, leaching out the substratum and mineralization process.

- The *in vivo* experiment to study effective control measured had five different treatments among which one was a physical technique while the other four used chemical treatments using different water repellent chemicals.
- The results of the data collected every month from October 2020 to August 2021, showed the reappearance of biofilm growth in months of July and August on the patches which were subjected only to physical scrubbing. This led to the conclusion that this treatment would not be effective for long term biofilm growth prevention.
- Among five chemical treatments, the treatment E which used Wacker SMK 1311 chemical gave the best results and hence is proposed as the treatment of choice for monuments having similar substratum and environmental conditions.
- The finding of the current study will provide substantial inputs for the conservation of monuments of the Pavagadh-Champaner Complex which is a designated UNESCO World Heritage site.