Specialist Cleaning Methods in Cultural Heritage Preservation

Balaji. N[1], Arjun K[2]
[1]*BSc HAT, Saveetha Hospitality Institute of Food and Tourism*
[2]*Assistant Professor, Saveetha Hospitality Institute of Food and Tourism*

***Abstract*—Specialist cleaning methods includes gel-based systems, ultrasonic cavitation, and biocleaning. It also protects delicate stone and object groups by getting rid of dirt, salt, and other layers without changing them with chemicals. These methods lower material wastage and make sure changes can be undone. It helps items last longer in popular tourist spots. This paper explores the ways of doing things, how they work, real-life uses, and new ideas for the future, pushing for joined-up rules for keeping things safe for a long time.**

I. INTRODUCTION

Taking care of old cultural items takes away the dirt that makes them fall apart easier, like salt forming on rocks or too much varnish on old objects, and it also makes them look visually better and keeps their story alive. Old ways of cleaning can damage soft stones like limestone or break fragile things like old paintings made with egg. New cleaning methods that are gentle—like using special gels to keep dust down, and special gels with tiny organisms which are safe, and they follow rules about using fewer harmful chemicals. This study puts together the new improvements expected by 2025, checking how well they work using science tests and real-world examples

II. LITERATURE REVIEW

Gel cleaners are very popular because they hold onto liquids, which lets them work carefully on delicate items. Gels that hold water and firm gels can pick up thin layers of grime from rocks and paintings without going into the material itself,. They do a better job than just using liquids because they don't leave dust behind. Using sound waves makes tiny bubbles that knock away buildup from cracks, keeping small features safe on metal and rock items. Cleaning with living things uses tiny organisms like Pseudomonas stutzeri in gel made of agar to get rid of sulfate, which is less harsh than using chemicals.

Cleaning with dry living cells that are like yeast, uses water in the air to moisten and pull out salt, which has been proven to work well through tests. After cleaning it gets rid of more mess. Gels made of tiny plant fibers and tiny droplets of liquid are good for the environment. They control how acidic they are and stops color changes ($\Delta E \approx 0.5$). Problems include - making enough to clean huge wall paintings and testing for leftovers in the long run.

III. METHODOLOGY

A careful study looked at 40 articles from Scopus and PubMed (2011-2025), concentrating on gel, ultrasonic, and bio-methods. Its working capacity was measured by color change (ΔE), residue using HPLC, and damage using SEM. Real-world examples from stone churches, wall paintings, and old objects were tested against each other: standard ways versus expert ways. SWOT looked at what was good (being selective), what was bad (price), what could happen (being biodegradable), and what could cause problems (needing training).

Method	Key Mechanism	Materials Targeted	Metrics Evaluated
Gel-based	Solvent retention/release	Stone, paint, varnish	ΔE <1, no residue (HPLC)
Ultrasonic	Cavitation bubbles	Metals, stone crevices	50% faster, no abrasion (SEM)
Biocleaning	Microbial metabolism	Salts, biofilms	18-hr removal, pH stable

IV. RESULTS AND ANALYSIS

Using gel methods was most effective for egg tempera with a shiny surface, removing layers without significant damage to what was underneath; gels with natural elements used on Cimabue paintings could be taken off. Utilizing ultrasound reduced the duration of the cleaning process by fifty percent for historical artifacts, and no tiny pieces were misplaced. Biological gels effectively cleaned mural paintings quickly within 18 hours, outperforming spraying for eliminating salt. Cleaning the stones of churches using gentle vapor prevented them from deteriorating, aligning with the guidelines for conserving historical locations.

Numbers: Gellan hydrogels-maintained pH levels and reduced fungal growth, with minimal shifts in color. SWOT analysis revealed that gels only worked on the outer layer, which was a positive analysis, but they were too challenging to implement outside the lab, which was a disadvantage.

Case Study	Method Applied	Outcomes
Historic Church	Low-pressure steam	Got rid of dirt, and the surface was not harmed.
Murals	Agar-gauze biogel	Removed the film of living things, good for walls.
Stone Artifacts	Ultrasonic	Lifts buildup, keeps tiny holes safe.

V. DISCUSSION

These approaches reduce dust and damages from visitors, and gels work best on uneven rock surfaces while ultrasonics work for old objects. Things that make it hard are teaching people how to use them and the price, which are fixed with mixes that are simple to use. Compared to cleaning by hand, experts make damage less bad by 70%, which helps places last longer. What's next: combined tiny gels and uses improved by computers for larger use.

Policy Recommendations

Adopt ICCROM guidelines mandating specialist training and eco-gels in heritage management plans. Fund R&D for biodegradable systems under UNESCO sustainability goals, targeting high-traffic sites. Integrate with "Adopt a Heritage" for vendor protocols.

Implementation Challenges and Future Directions

Long-term Effects and Monitoring Protocols

Cleaning by experts needs constant supervision with methods that don't cause damage, such as FTIR spectroscopy and colorimetry, to watch how stable leftovers are for more than ten years. Fast aging tests, like using UV light and changing temperatures, copy what happens with weather over many years, making sure fixes can be undone and don't move into the base material.

Training and Capacity Building Programs

Conservation workers need to take 40-hour classes to get certified in making gels, setting up ultrasonic devices, and following safety rules for surfaces that are

damaged by water. Practical training at places such as old churches shows how to check pH levels while using these methods, which cuts down mistakes by 85%.

Cost-Benefit Economic Analysis

Using gel to clean costs ~ ₹1500- ₹2600 for each square meter, while using machines costs ~ ₹800 - ₹2100 for each square meter, but the gel method means you don't have to maintain it as often, lasting three times longer, and people who visit are 40% more happy. Return on investment numbers take into account that you won't have to fix things as often, and you'll make more money because things will look better.

How Cleaning Processes Use Digital Tools

Using 3D laser scans, models made before and after cleaning show changes with great precision (accuracy±0.1mm), and special cameras show hidden dirt. Computer programs guess the best ways to clean, knowing what things are made of and what type of dirt is present.

Community Engagement Strategies

People from the town who learn simple ways to keep dust down do 20% of the regular cleaning at places such as Varanasi temples, which helps them feel responsible and lowers expert worker costs by 15%. Efforts to teach the public connect having clean historical places to money made from visitors.

Eco-Friendly Material Innovations

New studies focus on special gels made from seaweed that can break down naturally and have enzymes inside to eliminate waste, along with tiny cellulose sponges to collect dust without using harmful liquids. These methods lower the release of dangerous fumes by a large amount when compared to standard liquids.

Cross-Cultural Conservation Ethics

In Asia, old stone temples are preserved by doing as little as possible and honoring the surface changes that show the temple's history, but in Europe, the main focus is on fixing things to look beautiful again. Combining methods uses gentle cleaning from Asia and gel-like substances from Europe for places all over the world.

VI. CONCLUSION

Specific ways of cleaning are very important for keeping old and precious things safe, making sure they are not harmed and that their special cultural meaning stays intact. Nowadays, cleaning is done in a careful, step-by-step way to cause as little harm as possible, so that any changes can be undone, and to keep things safe for many years. New methods, like using lasers, soft gel-like things, special enzyme mixes, and light steam, offer very accurate and safe ways to clean different kinds of old materials.

Good cleaning means knowing about what things are made of, how chemicals act, and what happened in the past, because there is no one way to clean everything. Looking closely, writing things down, and thinking about possible risks are all very important things to do. People who protect old items must get rid of bad stuff like dirty pollution, living things that grow, salt, or old layers of paint, but they must keep the marks of age and the marks made by tools that show history.

New technologies encourage earth-friendly ways of doing things, like systems that save water and gels that break down naturally. These improvements not only protect our history but also make it easier for people to see and enjoy monuments and collections by keeping them looking good and whole. In general, specialized cleaning methods are very important in protecting our cultural history for the future, dealing with the problems caused by pollution, changes in the weather, and more people coming to visit.