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Stéphanie Eyssautier, Kamel Mouhoubi, Fany Reffuveille, Jean Luc Bodnar

To cite this version:

Stéphanie Eyssautier, Kamel Mouhoubi, Fany Reffuveille, Jean Luc Bodnar. Early detection of biofilm development on stone monuments thanks to pulsed IRT and SVD. Optics for Arts, Architecture, and Archaeology VII, Jun 2019, Munich, France. SPIE, pp.53, 10.1117/12.2526073 . hal-02945594

HAL Id: hal-02945594

https://hal.science/hal-02945594v1

Submitted on 12 Nov 2021

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SPIE. OPTICAL METROLOGY *Munich 24-27 June 2019*

Early detection of biofilm development on stone monuments thanks to pulsed IRT and SVD

Eyssautier-Chuine S.*, Mouhoubi K. **, Reffuveille F.*, Bodnar J-L.****

* **GEGENAA – URCA**, UFR Sciences Exactes et Naturelles - 51100 REIMS, FRANCE
** **ITheMM – URCA**, UFR Sciences Exactes et Naturelles - 51687 REIMS, FRANCE
*** **BIOS – URCA**, UFR Pharmacie - 51095 REIMS, FRANCE

Highlights

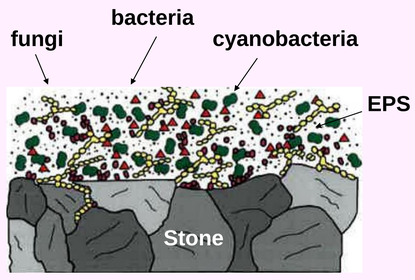
- Pulsed Infrared Thermography (IRT) tests detect early stage biofilm developed on stone monuments.
- Two renowned limestones used in buildings and monuments have been exposed to an outdoor biofouling test.
- The best Look Up Table (LUT) highlighting variations of energy between control samples and samples with biofilm has been selected.
- Singular Value Decomposition (SVD) has been to improve the detection of biofilm thanks to first EOFs.

State of the art

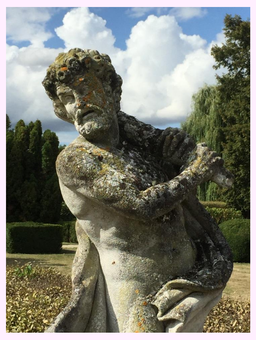
Biofilms are composed of micro-organisms such as bacteria, fungi, cyanobacteria which aggregate together on an inert surface by ion absorption.

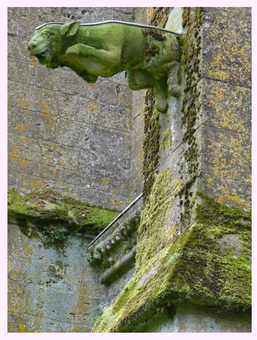
In Cultural Heritage, it is often regarded as a nuisance responsible for aesthetic defects and damages of material monuments and statues.

The early detection of biofilms can be helpful for a preventive action which is quicker and cheaper than a restoration work.



Gorbushina et al. 2007


Statue in the park of Courcelle-sur-Vesle castle (France)


Gargoyle of french gothic basilica (Avioth)

Outdoor biofouling test

Courville stone

Savonnieres stone

Photos of thin sections of stones in polarised light

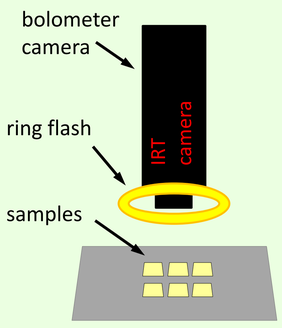
A natural biofouling test was set up in REIMS city (Easthern France).

Courville and Savonnieres stones have been used for construction in major buildings and monuments in Reims and the surroundings of Paris and now for restoration.

Both are limestones and have different texture, composition and petrophysic properties.

Small samples (2 x 2 x 1 cm) were collected after 6 months of outdoor exposure for the IRT study.

Detection of biofilms on stone by IRT (Infrared Thermography)

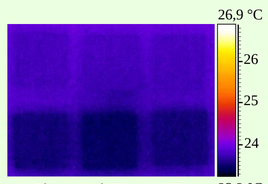


Setup :

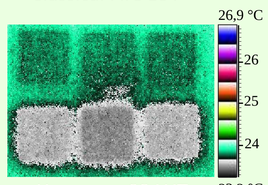
- a bolometer camera (5 s, 50 Hz)
- a ring flash for a light excitation of 5 ms (power : 3000 J).
- 3 small samples of control and 3 samples with non visible biofilm.

Before excitation: Fire LUT displayed slight colour variation between both stone batches.

Hue ramp 08 LUT was the best one to highlight slight variations of energy:
stones with biofilm in the bottom side were grey, controls in the upper side were green.



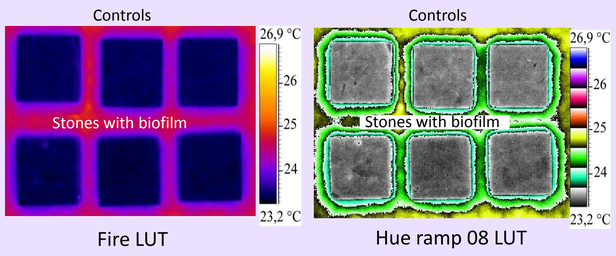
Classical Fire LUT



Hue ramp 08 LUT

Improvement of biofilm detection with post-processing SVD

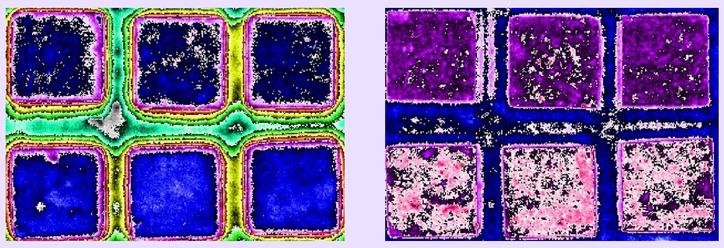
Courville stone



Fire LUT — Hue ramp 08 LUT

After a flash excitation:
Variations of temperature in Hue ramp 08 LUT between controls and stones with biofilm.

Highlighting of biofilm detection by SVD decomposition:

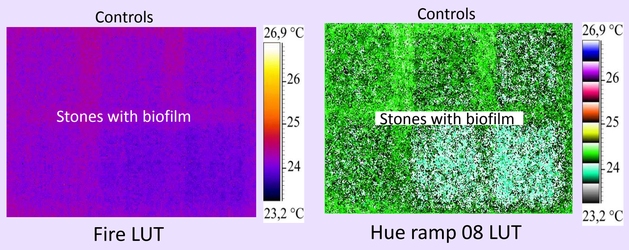

EOF 0 — EOF 1

First EOFs* detect variations of energy at the surface.

Biofilms are detected on the stone.

* Empirical Orthogonal Function

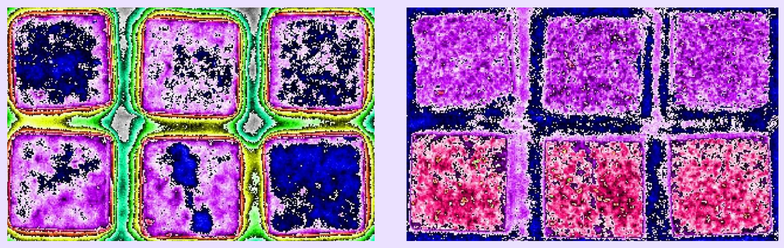
Savonnieres stone



Fire LUT — Hue ramp 08 LUT

After a flash excitation:
Variations of temperature in Hue ramp 08 LUT but only for two stones with biofilm.

SVD remove artefacts linked to the experimental conditions:


EOF 0 — EOF 1

EOF 1 detects biofilm on the three stones contaminated.

Conclusion

- The pulsed IRT is a non-destructive technique which allows early detection of biofilms as the pioneering colonizers on two different limestones and to react more rapidly and effectively to avoid biofouling of historical buildings.
- The choice of LUT is important to highlight variations of energy associated to the presence of biofilm.
- The SVD post-processing improves the detection thanks to the first EOFs and it gives a better reliability to results in removing artefacts.