ANDYSEZ 56
LAMPENFLORA YET AGAIN!
Thus *Lampenflora* Part 4

– Andy Spate

The very distinguished and knowledgeable Professor Arrigo Cigna has contributed a great deal to our understanding of cave environments particularly in relation to radon, carbon dioxide, cave environmental monitoring – and to the *lampenflora* problem. Below you will find a recent presentation from Arrigo given at the ISCA Congress in Slovakia in October 2010 (Cigna in press, 2010).

Many of us have tried to re-invent the wheel playing about with concentrations of sodium hypochlorite and calcium hypochlorite in spite of the admonishments of Tom Aley, for example, who has very fixed views on 5.25% hypochlorite (Aley and Aley 1992).

We have discussed other chemicals including potent biocides, altering light frequencies and the use of ultraviolet light in earlier ANDYSEZs (Numbers 48, 49 & 50 – look on your ACKMA CD ROM). All of these have drawbacks and some – such as the use of hypochlorite – may have very considerable impacts on cave environments – especially their biota.

The use of hydrogen peroxide has been trialed around the world. Unlike hypochlorite, hydrogen peroxide has no environmentally sensitive breakdown products. However, its effective use requires more input than one-off applications of hypochlorite – Arrigo and others such as Boston (2006), Faimon et al (2003) and Kubesova et al (2002) recommend three applications over a four week period.

Obviously this adds to the expense – but the environmental impacts (and the chlorine smell) in your cave will be much, much less. Obviously there are OH&S issues with peroxide – but there are to with hypochlorite – but we seem to have ignored these latter issues pretty well.

To quote part of the abstract from another paper at ISCA 2010 (Glazar and Mulec, in press):

> *In 2010, instead of bleach an environmentally-friendly and odour-free 15% buffered hydrogen peroxide – H_2O_2 (pH 7.5) was applied three times in a one month period. Once H_2O_2 is buffered, it becomes unstable, which is why its application on speleothems covered with lampenflora had to be done as soon as possible (<20 minutes).*
>
> *To increase the biocidal effectiveness and to remove the unaesthetic appearance, taluses [I think this means the macro-parts of the plants – i.e. weeding – hopefully your lampenflora is not that far advanced!] of mosses and ferns were removed first before the application of the H_2O_2.*
>
> *During winter spraying in 2010, the most exposed parts of the cave (~30%) of the illuminated cave) were treated … and the results for lampenflora growth control were very promising. This procedure is especially useful when applied to actively growing lampenflora. Once lampenflora is covered with flowstone, the oxidizing effect of H_2O_2 is drastically reduced [as with hypochlorite].*

So what is meant by buffering and why and how do we do it?

Faimon's et al (2003) details extensive and in-depth research on the use of hydrogen peroxide for *lampenflora* control. Unlike hypochlorite, peroxide can erode calcite – not much, but some.

Adding some of your local limestone or calcite to the peroxide solution for a few hours or overnight reduces or halts this issue. It just adds to the more complex approach of using peroxide rather than hypochlorite.

The disadvantages include:

- The need to buffer the peroxide solution;
- The need to use the buffered solution fairly quickly;
- The need for three or more repeat applications; and
- Possible greater need to address OH&S issues.

The advantage is a much more environmentally friendly approach. And I believe that we have much underestimated the OH&S issues with hypochlorite.

Please try this approach and report your results in the ACKMA Journal or on the ACKMA list. In a future ANDYSEZ we will explore how Cango Caves has controlled *lampenflora* with ultraviolet light – methods and practicalities – a guest ANDYSEZ from Hein Gerstner – little does he know!

Is there no end to his talents? Andy Spate shows his hand as an expert blacksmith at the *Pribylina Skanzen* (Slovak Open Air Museum) – ISCA Congress 2010.

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Faimon J, Stelcl J, Kubesova S and Zimak J 2003 Environmentally acceptable effect of hydrogen peroxide on cave *'lamp-flora'*, calcite speleothems and limestones, *Environmental Pollution 122*:417-422 [and emails to and from Dr Svatava Kubesova]

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THE PROBLEM OF *LAMPENFLORA* IN SHOW CAVES

– Arrigo A. Cigna*

INTRODUCTION

In a wild cave the flora, i.e. any kind of plants, exists only in a part close to a natural entrance where the outside light reaches the cave environment. According to the species, the plants may grow inside a cave until the light intensity ranges between one to three orders of magnitude less than outside.

Most of the show caves are fitted with a lighting system and in an area more or less around a lamp plants can develop. In general these plants are algae or mosses but sometimes also ferns till superior plants may develop and grow. This phenomenon was firstly studied mainly by Austrian scientists (Kyrle, 1923; Morton & Gams, 1925) and, later, in France (De Virville, 1928). A rather exhaustive book on the cave flora, with many references dating back to the XVIII century, is that due to Morton & Gams (1925).

Only in 1963 the word 'lampenflora' (a German word which means 'plants of the lamp') was firstly introduced by Dobàt (1963) and is presently adopted everywhere in the world to identify any kind of plants growing in the vicinity of lamps.

WHAT IS LAMPENFLORA AND HOW DOES IT DEVELOP?

The plants classified as *lampenflora* range, in general, from cyanobacteria (also known as blue-green algae), algae, lichens, mosses to ferns. Cyanobacteria, green algae and mosses are the most common components of the lampenflora in show caves, their abundance varies from cave to cave (Padisàk *et al.*, 1984; Grobbelaar, 2000; Aley, 2004). Algae and cyanobacteria exist in wild caves (Claus 1962,1964; Hajdu, 1966; Kol, 1967) also in the dark sections.

This means that a release of spores brought in by the visitors is not strictly necessary for a successive growth of these algae. When a cave is developed as a show cave the algae proliferate in the vicinity of the light sources thanks to the energy released by the lamps.
In general the *lampenflora* is firstly composed by algae at the beginning of its development, to be followed by mosses, ferns and sometimes by vascular plants (Mulec & Kosi, 2009). The negative effects of *lampenflora* is due to the fact that plants may produce weak organic acids, which in time can corrode both limestone and formations (Aley, 2004).

When a prehistoric cave is concerned the paintings may be seriously damaged as happened in Lascaux cave in France (Ruspoli, 1986). In addition, without any intervention the *lampenflora* spread rather quickly (e.g. in Baradla cave, Hungary (Hazslinszky, 2002), *lampenflora* doubled in 7 years) and may become an important source to colonise wide areas. A typical example is observed in Cango Caves, South Africa, where large surfaces of coral-like formations far away from the lighted section of the cave are covered by green algae.

Sweden's Hanne Hanne Öedin
and Italy's Professor Arrigo Cigna
at the 6th ISCA Congress in Slovakia.

Lampenflora's growth and distribution depend on light intensity, temperature, moisture and substratus. The lux (symbol: lx) is the unit of illuminance and it is used to measure the intensity of the light, as perceived by the human eye that hits a surface.

As a rough indication of the light intensity resulting in the development of 85% of the *lampenflora*, a value around 40 lux was measured

when the light was switched on for most or all the time that the caves were open. A continuous lighting yields more *lampenflora* growth than short periods of lighting for the same length of time because the adaptation of plants to light and dark phases requires both time and plant energy (Aley, 2004). The established *lampenflora* populations can survive long periods of very low levels of illumination or total darkness (Johnson, 1979).

Chlorophyll (types a and b) has two absorption peaks, in the ranges 430-490 nm and 640-690 nm. Therefore if a lamp has an emission spectrum in the range 500 to 630 nm the contribution to the photosynthesis process of green algae is reduced without important aesthetic problems. In Mammoth Cave, USA, lighting with LED at an intensity of 49.5 lx and a yellow light (595 nm) prevented re-growth for 1.5 years after complete *lampenflora* removal (Olson, 2002).

Sometimes a UV irradiation was used to suppress the *lampenflora* on account of its germicidal effect (Mulec & Kosi, 2009). Recently in Grotta Gigante, Trieste, Italy, a new set of germicidal lamps, provided with an electronic starter, which obtained the *2008 Green certificate*, in order to inhibit the development of lampenflora and to ensure an environmentally-friendly use of the cave were installed. These lamps, whose use aims at keeping under control the development of *lampenflora*, turn on when all the other lights in the cave are turned off (Fabbricatore, 2009).

Incandescent lamps produce an increase of the temperature and a decrease of the humidity. Within some tens of centimetres from the lamp the increase of temperature may be of the order of 10°C and the decrease of the relative humidity to 70-80%, this condition results in an algal growth unless the decrease of humidity is excessive and the algae cannot proliferate (Mulec & Kosi, 2009).

In fact *lampenflora* develops on moist or damp surfaces and therefore soft surfaces as cave sediments and moonmilch provide higher moisture storage than hard surfaces with the chance of luxuriant growths (Aley, 2004).

HOW TO CONTROL LAMPENFLORA

The most obvious action is the reduction of energy supply by both a reduction of the light emitted and the adoption of a light spectrum with a low emission in the wavelength absorbed for growth the *lampenflora* (Smith & Olson, 2007). Unfortunately such an action is not enough effective to solve the problem. Nevertheless it is convenient to use lamps with an emission spectrum poor of the wavelength mostly absorbed by *lampenflora*.

In Fig. 1 gives a graph showing where the maximum of the absorption peaks. The frequencies with the maxima from 460 to 453 nm around 600 nm and from 653 to 700 (particularly the latter) are the most dangerous for the proliferation (Caumartin, 1994). Preliminary experiments with cold cathode lamps reached a reduction of the growth of a green alga (*Dunaliella salina*) down to 57% of the control (Antrox, 2009).

The technique of switching out the light for a prolonged time interval (e.g. one month) counteracts the proliferation of photosynthetic organisms in caves but may favour the diffusion of especially resilient organisms as *Phormidium autumnale* (and generically cyanobacteria) by reducing competition (Montechiaro & Giordano, 2006).

It must be stressed that, notwithstanding the reduction of light plays a positive role in reducing the proliferation of *lampenflora*, sometimes a moss intertwined with cyanobacteria may cover relatively wide areas which were only occasionally illuminated (Giordano *et al.*, 2001).

When *lampenflora* proliferates, it is necessary to destroy it with chemical compounds. The herbicides have the disadvantage of being sometimes highly toxic for cave fauna and also the personnel must pay a special care. For this reason these biocides as DCMU, Atrazine, Simazine, Karmex, etc., are absolutely inappropriate in caves (Mulec & Kosi, 2009).

A comparison among an herbicide, sodium hypochlorite and sodium chlorate at the following concentrations:

- Karmex™ Du Pont 3 g/L water
- Sodium hypochlorite 2.75% Cl
- Sodium chlorate 30 g/m^2

gave similar results, but sodium hypochlorite had a faster effect while the results obtained with sodium chlorate were less homogeneous. The runoff of the solution should preferably be collected and disposed outside the cave- In any case after the treatment should the surface should be rinsed with water.

A test to evaluate the corrosive action of sodium hypochlorite was carried out on some broken formations. After 10 minutes of treatment about 41 mg/m^2 were dissolved without any further increase over 17 hours (Bertolani et al., 1991).

For this reason the treatment with sodium hypochlorite is currently adopted in the Frasassi Caves, Italy, since many decades with no disadvantages for he formations, which are as shining as when, they were discovered. But according some authors (Faimon et al., 2003; Mulec & Kosi, 2009) it represents a burden for the cave environment.

Therefore hydrogen peroxide, which is an environmentally friendly agent was proposed (Grobbelaar, 2000). The threshold concentration for the destruction of *lampenflora* was found to be 15% vol. but the solution attacked the carbonates with a dissolution rate around $2*10^{-2}$ mol m^{-2} h^{-1}.

In order to avoid such an effect a preliminary peroxide saturation was obtained by adding of few limestone fragments into the peroxide solution at least 10 hours prior to its application (Faimon et al., 2003).

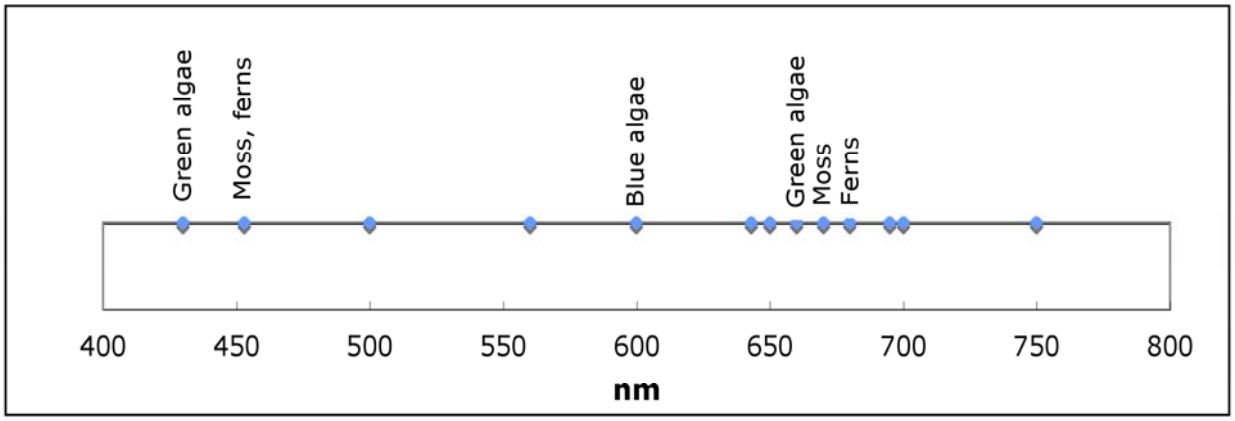

Fig. 1 – The most important absorption peaks of lampenflora (from Caumartin 1994, modified).

CONCLUSION

There are different actions to control the development of *lampenflora* in show caves. First of all, there is the reduction of energy introduced into the cave by the lighting:

- Lights switched on when necessary only
- Minimum distance of indicatively 1 m between lamp and cave wall or formations
- Emission spectrum with minima in the ranges 430-490 nm and 640-690 nm
- UV lamps switched on when visitors are absent

These actions can be implemented together or each one according to the local situation and possibilities. Obviously the lamps switched on only when the visitors are present in their vicinity reduce the energy release as well as the cost of electric energy.

Since the amount of radiation emitted from a lamp decreases as the inverse of the square of the distance, it is always convenient to avoid the placement of lamps too close to walls or formations also because the temperature increase can interfere with the growth of formations.

A spectrum poor of the wave length mostly absorbed by *lampenflora* can be easily obtained with discharge lamps (cold cathode lamps) or LED. The effect of UV irradiation was found to have only a transitory suppressing effect (Dobat, 1998).

In addition the effective range is between 50 and 70 cm for a 30 W lamp and therefore in order to have a wider area treated to a distance, e.g. of 3 m, a 400 W lamp would be required or a multiple low power lamps (Kermode, 1975). Some experiments are being carried on presently, as in Grotta Gigante (Trieste, Italy) where the whole electrical system has been replaced recently (Fabbricatore, 2009).

The result of the UV irradiation will be appraised in the very next future. In particular its effects should be considered with reference to the expenses of installation and maintenance.

Once the *lampenflora* is present, it is necessary to avoid its further development and destroy it by chemical methods:

- **No herbicides! Too toxic for the cave environment**
- Sodium hypochlorite 5%
- Hydrogen peroxide 15% vol

Herbicides, used frequently in agriculture, must be avoided because their degradation in the cave environment is rather slow and their toxicity may affects seriously the cave fauna.

Sodium hypochlorite treatment releases gaseous chlorine, which may have bad side effects on the cave fauna. Some air circulation may avoid such bad effects.

Hydrogen peroxide, once it is saturated with calcium carbonate, is surely the most 'friendly' chemical compound, but its use required some precautions by the personnel, while the personnel can apply the sodium hypochlorite without special attention.

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