Uranium accumulation in lichens

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The lichen *Trapelia involuta* has been found growing directly on the secondary uranium minerals meta-zeunerite [$Cu(UO_2)_2(AsO_4)_2.8H_2O$] and meta-torbernite [$Cu(UO_2)_2(PO_4)_2.8H_2O$] on uraniferous mine spoil heaps. *Trapelia* specimens present on this spoil have atypically dark brown-black (rather than pale red-brown) fruiting bodies (apothecia), the pigment being restricted to their outer walls and visible in thin section. X-ray element maps for U across transverse sections through the lichen-rock interface show U accumulation principally within the outer fruiting body (apothecia) walls of the lichen compared with their interior. These high U concentrations are not caused by the trapping of mineral particles as reported in previous studies since U:Cu, U:As and U:P ratios within the lichen differ significantly from those of possible trapped mineral phases. Complexing with oxalic acid and secondary lichen products can also be discounted as mechanisms since we identified calcium but no U-bearing oxalates within the apothecial walls. We irrigated sections with NaOCl confirming the presence of the secondary metabolite, gyrophoric acid within the main lichen body, but not within the apothecia, suggesting that this is also not responsible for the U accumulation observed.

Methodology

The pigment was extracted from *c.* 100 *Trapelia* apothecia by alkali extraction of *c.* 100 dark-coloured ascomata using a method modified after Ellis and Griffiths (1974). Pigment was extracted using hot KOH in a nitrogen atmosphere and then precipitated with HCl. The resultant precipitate was analysed using Fourier Transform-Infra Red (FT-IR) spectroscopy. The spectrum produced is typical of aromatic organic compounds and similar to that of humic acids (Filip *et al.*, 1974). This, together with the observation that the dark pigment is decolorized by the oxidising agent NaOCl, suggests that the compound is melanin or melanin-like. Melanin is known to form in non-lichenised fungal hyphae as a response to a wide range of environmental stresses, including metal contamination. Indeed a variety of heavy metals are known to induce or accelerate melanin production in fungi. Melanised cell forms have higher capacities to adsorb metals than albino forms with virtually all the metal being located in the melanised cell wall. Experimental studies have also shown that melanin and other biopigments have a high adsorption capacity for uranium (Ellis & Griffiths, 1974).

Discussion

Our study suggests that 'melanin-like' pigments, not previously reported within lichenised fungi, may be induced within ascomata of *T. involuta* in response to a metal-enriched environment. In the samples studied there is a strong correlation between the presence of melanin and high concentrations of uranium.

In the samples studied there is a strong correlation between the localisation of melanin and high concentrations of U, in agreement with experimental studies which show that melanin has a high adsorption capacity for U. It is possible that melanisation in *T. involuta* is an adaptive response to protect the ascospores, the sexual reproductive bodies formed within the apothecia, from the toxic effects of uranium.

This is the first time a mechanism of uranium accumulation, other than trapping of particulates, has been identified in lichens – an important step towards enhancing the use of lichens as biological monitors of radionuclides and in remediation processes.

References

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