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Lichens for bioremediation: an ecological, microbiological and chemical analysis on vegetal and fungal interactions with serpentine substrata. The case of the Balangero and Corio disused asbestos mine (Torino, Italy).

Since the end of XIX century, the interface between lichens and rocks has been recognized and examined as a place of considerable physical and chemical activity where weathering and pedogenesis processes develop (Syers and Iskandar, 1973). A biological and mineralogical multidisciplinary approach was widely adopted during the last century in order to evaluate the multiple aspects implicated in the interaction between the biotic and the abiotic components (Adamo and Violante, 2000). The fact that saxicolous lichens affect their rock substrates both in the natural state and when used as building stones has more recently led to a burst of studies relating to the general problem of the maintenance and the protection of Cultural Heritage (St.Clair and Seaward, 2004, with refs. therein). This renewed attention, combined with the development of several advanced microscopic and microanalytical techniques, has largely promoted, since the end of the 1990s, the knowledge of the biotic component of the lithic substrate and its weathering effects (de los Ríos and Ascaso, 2005).

In this context, following a lichenological and petrological multidisciplinary approach, lichen-serpentinite interactions were recently examined in an alpine environment (Favero-Longo, 2001-2002; Piervittori and Favero-Longo 2002; Piervittori et al., 2004a; Favero-Longo et al., 2005a). Although serpentinites have not been used to construct historic buildings and monuments as widely as other lithotypes, these rocks are extremely interesting because of their exploitation for asbestos.

In this PhD project, the lichen weathering of asbestos-rich serpentinites and other asbestos-rich substrata has been examined. Mineralogical-lichenological techniques have been innovatively combined with chemical ones, in order to reproduce under controlled conditions the different bioweathering factors and mechanisms which come into play in the environment and to highlight their effects on asbestos fibres. Because of the well-known toxic effects of asbestos, this research on the lichen weathering action bears an interest overcoming the traditional implications in soil dynamics and Cultural Heritage conservation, showing consequences for environmental safety.

Asbestos toxicity has been examined and proven in many laboratory studies on unweathered fibres (Kane et al., 1996, with refs. therein). This research on lichen biodeterioration of asbestos minerals in the disused chrysotile mine of Balangero and Corio shows that fibres at the surface of rocks and buildings are widely colonized by microorganisms and, particularly, by lichens. Beneath lichens, chrysotile, and even crocidolite, are significantly modified in their chemical composition with respect to their standard. Since physical and chemical characteristics are known to be responsible for asbestos toxicity (Fubini and Otero-Areán, 1999), this result indicates that laboratory data on the toxicity of unweathered fibres can not be extended to fibres which in the environment support biological colonization.

Since reactivity tests could not be performed directly on the lichen-colonized fibres, chrysotile chemically similar to the one detected under lichens in the field was reproduced in the laboratory, following a biomimetic approach. This weathered chrysotile showed a reduction in Fenton activity, which is commonly assumed to be an important factor in fibre toxicity. The chelating action of both oxalic acid (lichen primary metabolite), norstictic acid and pulvinic acid (low soluble lichen secondary metabolites) turned out to be responsible for the surface modifications of the fibres and thus to be important for the inactivation process.

Lichen growth on asbestos-rich substrata thus appears as a possible tool for bioremediation in the environment since, when colonized, the fibres appear to be modified in their toxic properties. In the case of the Balangero asbestos mine, lichens have already developed low covers on asbestos-rich serpentinites, and asbestos-cement roofs show lichen covers up to 25 %. Appropriate biotechnological techniques, however, should be required to speed up and increase the colonization processes. By contrast, literature on lichen "cultivation" in the field suggests that any effort to artificially favour lichen colonization on rocks is extremely problematic. This topic was also confirmed by early attempts in culturing lichen propagules (isidia of *Xanthoparmelia tinctina*) and thalline fragments (*Candelariella vitellina*) on the Balangero serpentinites. Even if good results were obtained in terms of vitality and early developmental stages of propagules, the very low growth rate of transplanted propagules clearly shows that lichens, slow-growing organisms, are inadequate to be used for active bioremediation applications.

Nevertheless lichens, by selectively and spontaneously colonizing the asbestos rich rock surfaces, appear as good promoters of natural attenuation mechanisms which, in the case of the Balangero and Corio asbestos mine, are already effective fifteen years after the mining activity stopped in 1990.

This attitude in colonizing fibre-rich surfaces suggests that lichens and other microorganisms could have always played a role in the natural attenuation of asbestos hazards in all those areas where asbestos naturally occur (such as Western Alps) but fibres were never commercially exploited.

Since lichens contribute in covering and inactivating fibres, priorities in removal of asbestos-cement roofs should also be reconsidered. Until now lichen-bearing, asbestos-cement roofs have been considered more dangerous than bare ones and preferentially removed. In this context, however, further studies are necessary to establish what lichen cover could be effective in reducing the fibre hazard.

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