Crystal chemical and structural characterization of fibrous tremolite from Susa Valley, Italy, with comments on potential harmful effects on human health

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ABSTRACT

This study is part of a broad research project devoted to the “amphibole fibers environmental problem” as related to the proposed excavation of the Susa Valley railway tunnel. In this locality, tunnel excavations are planned through metamorphic formations containing amphibole asbestos minerals, and this may give rise to worker health and public environmental issues. The Susa Valley tremolite shows a marked fibrous character, a small reduction of fiber size under grinding, and a consistent increase of the surface area. From the toxicological point of view, such tremolite fibers have been shown to be very effective in the generation of reactive oxygen species. They exhibit a very high cellular reactivity as a consequence of their morphology, structure, and crystal chemistry. Results of combined electron microprobe analysis, Mössbauer spectroscopy, and parallel-beam X-ray powder diffraction are reported for fibrous tremolite from a serpentinite-chst from the “Unità Oceanica della Bassa Val di Susa” collected near Condove, Susa Valley, Italy. Data indicate that Fe2+ (84% of Fe tot) is located at both the (M1 + M3) and M2 sites and that Fe3+ is at M2, in an approximate 3:2:1 ratio, respectively. No evidence of a split M4 site has been observed. The presence of M1+M3Fe2+ is confirmed by FTIR spectroscopy to be distributed 70% at M1 and 30% at M3. Both the composition (Ca0.18Fe0.01Na0.05Mg3.84Mn0.02Fe0.02Mg0.25Mg0.06Si0.00O2(OH)1.95Fe0.03Cl0.03) and the cell volume 907.37(1) Å3 of the fibers are close to those expected for end-member (Ca/Mg = 2/5) tremolite.

Keywords: Fibrous tremolite, amphibole crystal chemistry, Mössbauer spectroscopy, Rietveld method, electron microprobe analysis, Susa Valley, Italy, Trans European Network

INTRODUCTION

In the near future, numerous construction projects are likely to be carried out in northern Italy, all belonging to corridor 5 of the TEN (Trans European Network). In particular, some high-speed railway lines such as Turin-Lyon and Genoa-Milan will involve tunnel excavations occurring in metamorphic formations, such as serpentinites, in which zones containing asbestos minerals may be found. These excavations give rise to worker health and public environmental issues (Piolatto et al. 1990; Astolfi et al. 1991). This contribution is a part of a broad research program devoted to the complete definition of the “amphibole fibers environmental problem” as related to the proposed excavation of the Susa Valley railway tunnel. Its goal is to provide up-to-date, clear information to both policy-makers and stakeholders to minimize human exposure to potentially harmful materials. When inhaled, asbestos fibers may give rise to either non-tumor diseases or malignant tumors in the lungs (Martuzzi et al. 1999) and pleura (Mastrantonio et al. 2002). Particular attention should be paid to the effects of asbestos on the rise of pleural mesothelioma (Bignon et al. 1996). The main features of such tumors are particularly long latency, occurrence related to individual susceptibility, a difficult diagnosis, a previous exposure only to asbestos of the amphibole group (Constantopoulos et al. 1987), and most of all, the capability of appearing even after the inhalation of an extremely low asbestos concentration known as triggering dose (U.S. National Research Council 1985; Piolatto 1996). The mechanism through which asbestos fibers may give rise to cancer is not yet completely clear. Many authors agree in attributing the biological activity of the fibers to numerous factors: dimension (Stanton et al. 1981), chemical composition (Fubini 1996; Gilmour et al. 1997), surface properties (Fubini 1993), solubility, and bio persistence (Liu et al. 2000). The diameter and length influence the mechanism of capture and rejection of the fibers. The results of in vitro and in vivo studies show that the longer and thinner fibers are the more dangerous. In fact, the fibers with diameters less than 3 μm and lengths more than 20 μm are partially phagocyted by the alveolar macrophages, with the consequent release of chemical species capable of reacting with the oxygen, causing damage to DNA due to oxidation and modification of the cell’s surface. Chemical composition may also contribute to the occurrence of cancer through the presence of iron that may give rise to species capable of reacting with the oxygen, causing the already-mentioned damage. Recent Italian legislation (directives 67/548/CEE and 97/69/CEE) takes into account the above concepts in labeling and classifying carcinogenic