Biodurability of talc

JOSEPH B. JURINSKI¹ AND J. DONALD RIMSTIDT²

¹NuChemCo, Inc. 334 Commerce Street, Alexandria, Virginia 22314, U.S.A.
²Department of Geological Sciences, Virginia Polytechnic Institute and State University, Blacksburg, Virginia 24061, U.S.A.

ABSTRACT

Dissolution rates of a well-characterized sample of powdered talc were measured in solvents that mimic fluids found in the human lung. These experiments found that talc dissolution rates were the same for pH controlled aqueous solvents, phosphate buffered saline solution, and modified Gamble’s solutions. Variation of solvent chemistry, including the addition of organic chelators and proteins at intercellular fluid concentrations, does not markedly affect the measured dissolution rate of talc at 37 °C. The data further indicate that the dissolution mechanism for talc in aqueous solutions is independent of pH over the range of 2 to 8. The dissolution rate at 37 °C, determined by measuring the silicon release rate per unit surface area of talc in a mixed-flow reactor system, is 1.4 ± 1.0) × 10⁻¹¹ mol Si/m²·s. Application of a geometric shrinking particle model using this dissolution rate results in an estimated lifetime (upper limit) of approximately 8 years for a 1 µm talc particle under pulmonary conditions. Talc dissolves considerably faster than quartz, but slower than chrysotile and olivine in the body. These data can be used to place constraints on the role of particle dissolution in the disease models associated with airborne respirable mineral particles.

INTRODUCTION

The recent focus on the behavior and control of inhaled mineral particles by the medical and regulatory communities presents geochemists an opportunity to extend principles traditionally used in characterizing the dissolution of minerals into the new field of biologically based dissolution studies. Adaptation of traditional mineral dissolution rate studies to mimic the physical and chemical conditions encountered in the lungs allows geochemists to estimate mineral biodurability in the lung through calculation of residence times based on the dissolution clearance mechanism. Mineral dusts are pervasive in our environment and we are continuously exposed to them on a daily basis. Mechanical and chemical weathering processes produce readily suspended dusts, which may then be taken up into the lungs (Klein 1993). The respiratory exposure to specific mineral dusts has long been known to cause adverse heath effects, including scarring and thickening of the tissues of the lung, and the development of cancer (Kane 1993). For instance, exposures to airborne asbestos minerals are known to cause mesothelioma, lung cancer, other cancers, and other lung diseases, such as asbestosis. Similarly, exposure to elevated concentrations of quartz can produce silicosis, and occupational exposures to high concentrations of relatively "pure" airborne talc dusts have been linked to talcosis, a relatively benign lung pneumoconiosis (Gamble 1986). The effects of exposure are considered severe enough that exposures to dusts, including mineral dusts, are regulated in the workplace. The United States Environmental Protection Agency also regulates fine airborne particulate matter, which includes mineral dusts, through Clean Air Act regulations (USEPA 1997).

Silicates are used extensively in industry. Olivine is processed as a source of magnesium and olivine sands are used in high temperature foundry operations and as a substitute for quartz sand. The number of workers exposed regularly to olivine is, however, relatively small. There have been no reports of occupational respiratory disease associated with exposure to olivine, although there is no epidemiological data describing the effects of exposure (Gamble 1986). Chrysotile asbestos is considered a human carcinogen, and regulated as such in the U.S. workplace (Stayner et al. 1996; USDOL 1994). Historically, chrysotile was used extensively in the United States. Chrysotile was incorporated into a wide range of commercial products due to its thermal stability and tensile strength, including thermal systems insulation, vehicle brake linings, transite siding, vinyl floor tile, and decorative or thermal architectural finishes. Exposures to chrysotile were associated with the processing of the mineral and the manufacturing and application of asbestos containing products. Exposures to crystalline silica (mostly quartz) are widespread, both from the workplace and the environment. Exposure to crystalline silica in the workplace has been linked to silicosis, a progressive pneumoconiosis. Debate on the role of crystalline silica in the development of cancer in exposed populations continues, but it is unlikely that significant cancer risk is associated with exposures to crystalline silica at current occupational exposure control limits (McDonald 1995). Talc is used extensively in industry and is incorporated into a wide range of products including paints, coatings, cosmetics, pharmaceuticals, and as coatings on paper. As a result, the cohort of potentially exposed workers is much larger than the population of olivine-exposed workers. This use results in exposures to a large segment of the