Sources of aluminum

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On May 18, 1980, Mt. Saint Helens erupted and showered the state of Washington with volcanic ash. This ash contained 17–19% aluminum by weight (Anthony Irving, University of Washington, personal communication). In such circumstances, the question of the source of aluminum does not seem difficult. Eight per cent of the earth’s crust is aluminum, making it the third most common element. However, most of this metal remains in the rocks or soil as insoluble alumino-silicates. With weathering, it may turn to aluminum hydroxide. The concentrations in ground water are usually between 10–1000 μg/l (0.5–37 μmol/l; one part per million = 1000 μg/l) In sea water aluminum is only 1 μg/l [1]. Acid rain can enhance aluminum mobilization; whereas the aluminum concentration in deep soil and springs are negligible in the forests of Washington, the concentrations increase to 602 μg/l (67 μEq/l) in New Hampshire where excess sulfuric acid is found in the rain. Such leaching is a modern phenomenon [2].

Aluminum is not found in significant quantities in normal animals. In humans, the total body aluminum load is normally less than 30 mg [3]. Thus, the question becomes more complex, and we not only must know the source of aluminum, but how it gains entrance to our system. A study of normal individuals in the United States and in Australia showed similar tissue concentrations of 1–6 mg/kg in the liver, spleen, bone, heart, muscle, and brain. In the lungs the levels were 43–67 mg/kg; these were significantly higher in the Australians and correlated with age [3]. Thus, some aluminum may be inhaled, but pathologic abnormalities have been associated with inhaled aluminum only in workers in industrial environments [4, 5]. Patients with chronic renal failure not yet on dialysis had concentrations of 2–35 mg/kg in their tissue, and those on dialysis were 9–243 mg/kg, with high concentrations in liver, spleen, and bone. Some of the dialysis patients had encephalopathy, and their aluminum levels were significantly higher, from 41–493 mg/kg [3]. These high levels of aluminum have now been shown to be toxic to
brain, bone, and marrow. The aluminum in such cases comes from parenteral solutions or oral substances.

**Parenteral sources**

*a) Dialysate* Persons with excess aluminum from parenteral sources have all received their aluminum from the hands of the medical profession, since this route of administration does not occur naturally. The most serious cases of aluminum toxicity have therefore been iatrogenic, and have been seen in patients exposed to large amounts of aluminum via dialysis or intravenous solutions.

Dialysis encephalopathy was first described by Alfrey in 1972 [6], and he gave evidence that aluminum was the etiology in 1976 [7]. At that time he postulated that the elevated aluminum seen in the patients with encephalopathy came from the antacids they ingested. Investigators in England found that the cases of encephalopathy showed geographical clustering, and thought that the aluminum source was the water supply [8]. It now appears that aluminum from both sources may cause intoxication.

High dialysate aluminum due to increased aluminum in the tap water may cause epidemics of dialysis encephalopathy. A survey of European dialysis centers showed that encephalopathy had an uneven geographical distribution. Ninety-two per cent patients with dementia had dialyzed against untreated water, whereas 54% of non-affected patients had used untreated water [9]. In another survey, the incidence of this disease was shown to be significantly correlated to the water aluminum in 18 dialysis centers in Great Britain [10].

What is the source of this aluminum? The first documented case of dialysis encephalopathy in Washington occurred just three months after the St. Helens eruption. The patient lived in a small town near the mountain, and dialyzed at home. We speculated that the aluminum-laden ash had contaminated the water supplies, but when we measured water aluminum from 5 towns around the state, we found concentrations between 2–10 μg/l. The water from the patient's home, however, contained 125 μg/l. Further investigation showed that the city water department had added aluminum to flocculate the water, making it appear clearer. Aluminum is able to bind to particulate matter in water, causing it to precipitate, and the resulting water may be clear, but will often have elevated aluminum concentrations. This is the most common cause of high aluminum in tap water, especially in cities that depend on muddy rivers for their water.

In Chicago, for example, there were no cases of encephalopathy prior to 1972. Suddenly a devastating epidemic was seen, and 20 patients died of encephalopathy within 4 years. When Alfrey proposed that aluminum caused