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Biogeochemical Monitoring in Medical Geology

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Biogeochemical Mapping

How can we determine the distribution of metals and other elements in our environment? The Geological Survey of Sweden started an innovative monitoring of metals in a monitoring/mapping program in 1980. Before 1980, traditional inorganic stream sediments were used, a method still employed all over the world, but not really suitable for medical work. A new method is used, whereby metal concentrations are determined in organic material consisting of aquatic mosses and roots of aquatic higher plants. These are barrier-free with respect to trace metal uptake and reflect the metal concentrations in stream water (Brundin 1972, 1988, Kabata-Pendias,1992, Selinus 1989). Aerial parts of many plant species do not generally respond to increasing metal concentrations in the growth medium because of physiological barriers between roots and above-ground parts of plants. These barriers protect them from uptake of toxic levels of metals into the vital reproductive organs. The roots and mosses, however, respond closely to chemical variations in background levels related to different bedrock types in addition to effects of pollution. The biogeochemical samples provide information on the time-related bioavailable metal contents in aquatic plants and in the environment. One great advantage of using biogeochemical samples instead of water samples is also that the biogeochemical samples provide integrated information of the metal contents in the water for a period of some years. Water samples suffer from seasonal and annual variations depending on, for example, precipitation.

The mapping program now covers about 65% of the land area of Sweden (40,000 sample sites, one sample every 6 km^2), where about 80% of the population of Sweden is living. This means that there is now available an extensive analytical data base for use in environmental and medical research (Freden 1994).

Cadmium in Southern Sweden

One example of the use of biogeochemical monitoring concerns high cadmium contents in Sweden. In noncontaminated, noncultivated soils, Cd concentration is largely governed by the amount of Cd in the parent material (Thornton 1986). If the substrate concentration is higher than in background concentrations, Cd is readily taken up by roots and is distributed

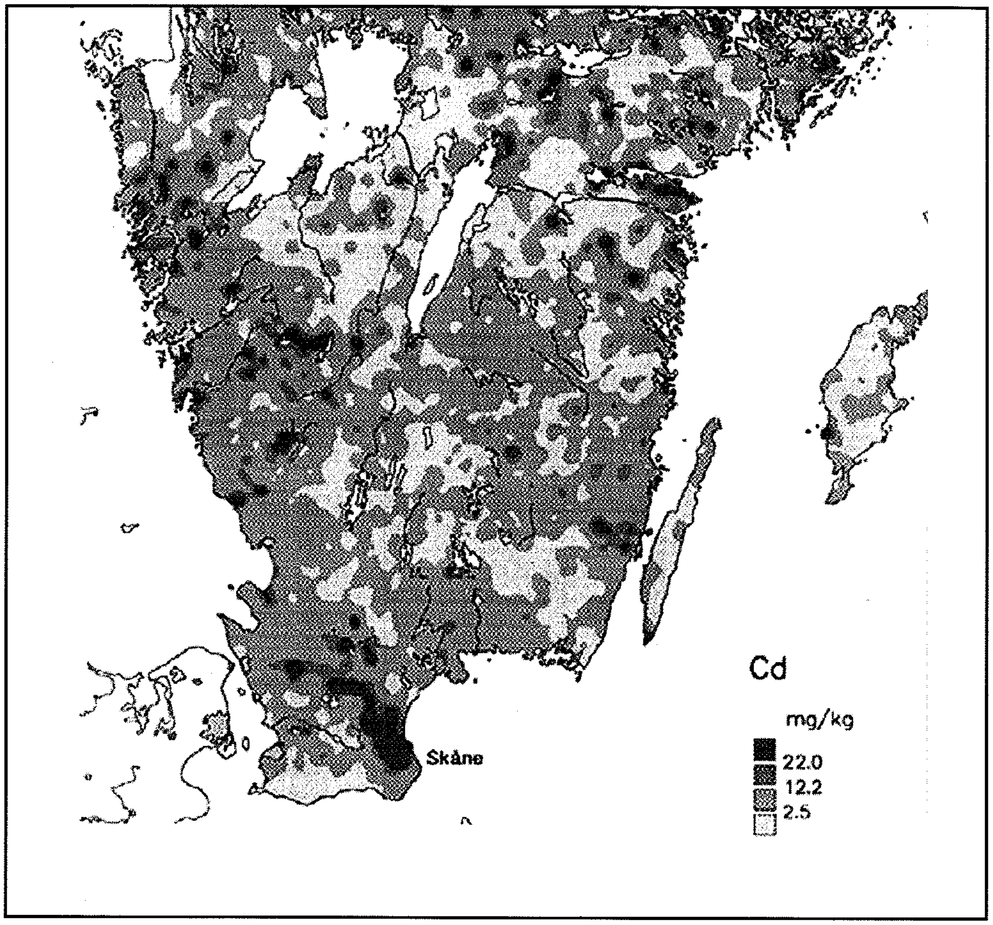

Figure 21.1: Cadmium (Cd) in biogeochemical samples in southern Sweden.

throughout the plants. The amount of uptake is influenced by soil factors such as pH, cation exchange capacity, redox potential, phosphatic fertilization, organic matter, other metals, and other factors. In general, there is a positive, almost linear correlation between the different Cd concentrations in the substrate and the resulting Cd concentration in the plant tissues (Selinus 1983, 1988).

Cadmium levels in biogeochemical samples (roots and aquatic mosses) from southern Sweden are shown in Figure 21.1. The contents are enhanced in the southernmost counties (Skåne) of Sweden and along the west coast of Sweden. The latter distribution is derived mainly from transboundary atmospheric transport and deposition of anthropogenic origin. The contents of Cd in the southernmost part are, however, much higher, and the highest levels so far detected since 1982 are located in this region. This region is a densely populated farming region from which growing crops are distributed to the rest of Sweden. Samples of autumn wheat have been taken in certain geographical regions. The results showed that samples from Skåne had an average of 73 μg Cd/kg dry weight, with several areas exceeding 100 μg Cd/kg dry weight. In comparison, an area in central Sweden yielded on analysis only 29 μg Cd/kg dry weight on average in autumn wheat. The Cd contents in wheat from Skåne are therefore a matter for concern. In this region drinking water is taken from many wells. In those that have been analyzed for Cd, the results show an almost identical distribution of high Cd contents as depicted in the biochemical map. For drinking water, the WHO has set a limit of 5 μg Cd/l. In comparison, the wells in Skåne, within the region with high Cd burden, have levels of max 400 μg Cd/l.

Several factors may interact with each other: for example, deposition of airborne Cd, as well as acid rain from Eastern, Western, and Central Europe. Cadmium may also originate from phosphate fertilizers used in agriculture. However recent studies have shown that the high contents of Cd are probably derived from sandstones with disseminated Cd. Therefore, we have a reason to believe that we have a connection between geology, acidification, and possible health effects caused by cadmium.

Use of Biogeochemistry in Medical Geology

The inverse relationship between cardiovascular disease and water hardness was first reported in the U.S. in 1956 and from Japan in 1957. A significant inverse relationship has been found between water hardness and total cardiovascular mortality. A higher sudden death rate in soft water areas compared to hard water areas are also reported. In the WHO myocardial infarction registry network, all cases of myocardial infarction were registered in a standardized way in 15 WHO countries in Europe. Higher rates of ischaemic heart disease (IHD) were found in towns served by soft water than in towns with hard water. In Sweden it has shown that water hardness (Ca + Mg and other minor constituents) and the sulphate and bicarbonate concentrations of the drinking water were inversely related to IHD as well as stroke mortality. The variation in the drinking water composition in these areas reflects the geological variation in the region as demonstrated by the biogeochemical sampling program (Nerbrand 1992).

Childhood diabetes is almost exclusively of the autoimmune insulin-dependent type (type1). The genetic prerequisites are clearly not sufficient causes of the disease. Descriptive studies from population-based incidence registers from the countries in Scandinavia have shown a significant within-country geographical variability in insulin-dependent diabetes incidence rates that cannot be explained by a slight south-north gradient only. A case control study has been designed comparing cases and controls as to estimates of zinc obtained in biogeochemical samples from areas of residence. A high water concentration of zinc was associated with a significant decrease in risk. This provides evidence that a low groundwater content of zinc that may reflect long-term exposure through drinking water is associated with later development of childhood onset diabetes (Haglund 1996).

Another example of the use of biogeochemistry in medical geology is the work on moose (Frank). The biogeochemical technique and animal monitoring technique by using moose as a monitor for mapping the bioavailabilty of elements in the environment complement each other on different levels in the food chain. The results using biogeochemistry and those using organ tissues from the moose collected during the same period of time appear to be remarkably similar, despite higher trophic level of the latter. The two methods elucidate the usefulness of the techniques in monitoring and detecting metal burdens of regions on toxic levels as well as deficiency of essential elements

(Selinus 1996, 2000).

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