Molybdenosis: A Potential Problem in Ruminants Grazing on Coal Mine Spoils

JAMES A. ERDMAN, RICHARD J. EBENS, AND ARTHUR A. CASE

Highlight: Copper-to-molybdenum ratios in all but two sweetclover samples collected on spoil at eight coal mines in the Northern Great Plains ranged from 0.44:1 to 5:1. Ratios of 5:1 or less in forage are reported to cause molybdenosis, a nutritional disease occurring in molybdic regions of the world. Therefore, if the major forage on coal-mine spoils is sweetclover or other species with similar Cu:Mo ratios, molybdenosis may be expected to occur in cattle and sheep grazing in these areas.

Molybdenosis is a copper-deficiency disease which occurs particularly in cattle and sheep and which is caused by the depressing effect of molybdenum (Mo) on the physiological availability of copper (Cu) (Dye and O'Harra 1959; Clawson et al. 1972; Case 1974). Characteristic symptoms in cattle are scouring, weight loss, depigmentation, reproductive impairment, and even death. Calves are most susceptible, and early symptoms are often irreversible. Although there appears to be no evidence that nonruminants suffer from Mo toxicity, various osteodystrophic conditions may occur in horses fed on high Mo forage over an extended period of time (Dye and O'Harra 1959).

Sweetclover (*Melilotus officinalis* and *M. alba*) is known to be a Mo accumulator, as are many other legumes; it is abundant and widespread on many coal mine spoils in the Northern Great Plains. Legumes are recommended in seed mixture used for land reclamation because of their nitrogen-fixing capability. Sweetclover is considered to be an especially effective plant for spoil-bank stabilization. This species is highly nutritious for livestock, ranking with other cultivated legumes in forage value, and is considered by some ranchers to be superior in productivity and nutritional quality to several of the native grasses in the Northern Great Plains (Miles 1970).

The availability of Mo to a plant is strongly affected by soil pH (Alloway 1973). Its availability is therefore enhanced by the more alkaline conditions that prevail in much of the West. Webb and Atkinson (1965) reported that 5 ppm Mo in forage is the approximate upper level tolerated by cattle, although more recently values as low as 2 ppm have been considered important in Mo-induced hypocuprosis in cattle (Alloway 1973; Thornton 1977. Others believe that it is not the concentration of Mo alone, but the ratio of Cu to Mo, that is the common cause of molybdenosis. The disproportion of these elements ranges from abnormally low levels of Cu and moderately high concentrations of Mo (distinguished as hypocuprosis or "peat scours") to unusually high concentrations of Mo with normal Cu levels (distinguished as molybdenosis or "teart disease"). These two conditions of element imbalance may, for convenience, be termed molybdenosis. A recommended Cu:Mo ratio for cattle is about 6:1, whereas a ratio of less than 2:1 will most likely cause molybdenosis symptoms to develop (Dollahite et al. 1972). Sheep are somewhat more tolerant of Mo (Dye and O'Harra 1959), although ratios of less than 5:1 have caused swayback disease in lambs as well as bovine hypocupraemia in Britain (Alloway 1973).

Authors are botanist and geologist, U.S. Geological Survey, Denver, Colorado 80225, and veterinary toxicologist, College of Veterinary Medicine, University of Missouri, Columbia 65201.

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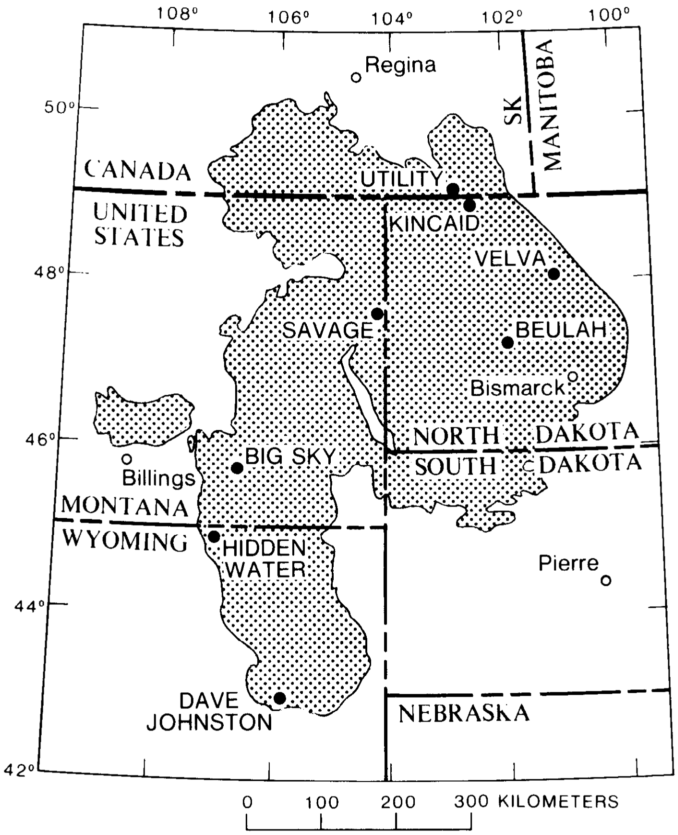

Fig. 1. *The Northern Great Plains coal province, showing locations of the eight surface mines sampled for sweetclover and associated spoil material. Map adapted from Whitaker and Pearson (1972); U.S. Geological Survey (1974).*

Native soils may contain sufficient Mo to cause molybdenosis in range livestock in some areas of the United States, particularly in Nevada and California (Kubota 1975). The replacement or alteration of native soils with spoil materials from mining operations can lead to more widespread molybdenosis problems, as was demonstrated in connection with a clay mine operation in Missouri (Ebens et al. 1973). The development of coal resources in the Northern Great Plains, particularly by surface mining, led us to examine the Cu:Mo ratios in samples of sweetclover that grew on spoils from eight coal mines in this region.

Methods

We conducted the field work during late summer of 1974. Samples of sweetclover and associated soil and/or spoil material were collected from 10 randomly selected sites (in which sweetclover could be found) at each of eight surface mines scattered throughout the Northern Great Plains (Fig. 1). A sample of spoil material or a spoil-soil mixture (where topsoiling had been attempted) was collected to a depth of about 20 cm. The sweetclover sample consisted of the above-ground portion of a plant growing within 1 m of the soil sample. Composite samples were collected from an area as large as 10 m^2 when single plants were not large enough. Although we wished to sample only yellow sweetclover (*Melilotus officinalis*), at the Big Sky and Utility mines this species had matured to the point where only stems remained and the later-maturing white sweetclover (*M. alba*) was sampled instead. Both species occurred at most mines, yellow sweetclover appearing to be the more abundant.

Samples of sweetclover were first dry-ashed at 450°C for 24 hours. Cu and Mo analyses of the ash were performed using atomic absorption spectrophotometry and thiocyanate methods, respectively (Reichen and Ward 1951; Nakagawa 1975). Because many reports on

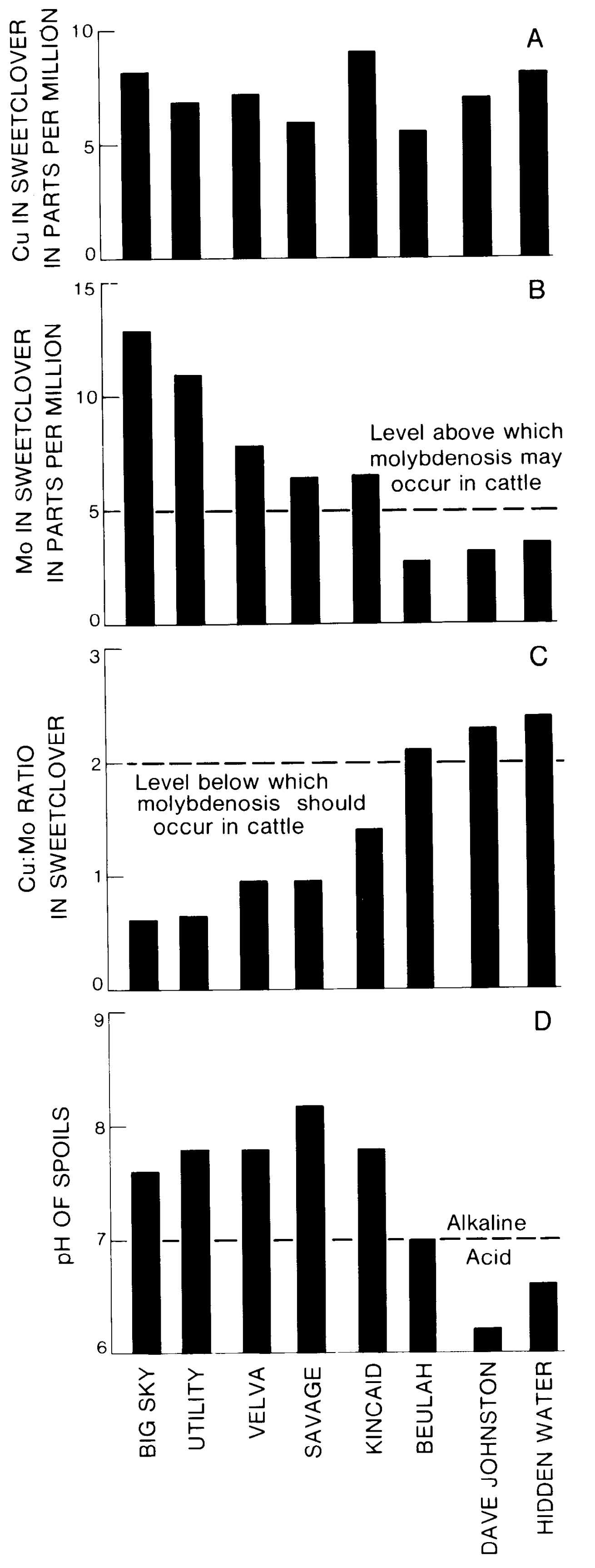

Fig. 2. *Mean copper (A) and molybdenum (B) concentrations in sweetclover, Cu:Mo ratios in sweetclover (C), and pH values of associated spoil materials (D) at eight surface coal mines in the Northern Great Plains. Each mean is based on 10 randomly selected samples.*

element concentrations in sweetclover are given on a dry-weight or moisture-free basis (see, for example, Furr et al. 1975), we converted the element concentrations that were reported by the analysts on an ash basis to a dry-weight basis. Samples of spoil materials were ground to pass through an 80-mesh sieve. Soil pH was measured using a hydrogen ion-specific glass electrode in a water-saturated paste.

Results

An analysis of variance procedure, which tested the differences between and within mines, demonstrated significant differences ($P < 0.05$) between the mines for all variables represented in Figure 2 (Cu, Mo, and Cu:Mo ratios in sweetclover, and pH in spoils). The Cu levels in sweetclover, however, were not very different between mines, and are about normal for forage (Dye and O'Harra 1959). The Mo levels and Cu:Mo ratios in sweetclover indicate that the potential for molybdenosis exists to varying degrees at all mine spoils that we sampled.

Duncan's multiple range test showed that the means for Mo fall into two groups. One group represents samples from the Beulah, Dave Johnston, and Hidden Water mines: the Mo averages range from 2.6–3.4 ppm. Spoil samples from these three mines were slightly acid or neutral. The second group of means ranged from 6.4–13 ppm Mo (Fig. 2); these concentrations are considered unusually high for typical forage and are all above the critical level of 5 ppm for Mo. Moreover the Cu:Mo ratios for samples from the mines in this group are below the conservative critical 2:1 ratio. Samples of spoils from these five mines were definitely alkaline, which probably accounts for the higher levels of Mo in the sweetclover.

The data indicate that the Mo concentrations in sweetclover growing on coal mine spoil banks at the mines studied are sufficiently high to induce metabolic imbalances in cattle and possibly in sheep and native ruminants at subclinical, if not acute, levels, assuming the animals were to feed predominantly on this or similar legumes. The low Cu:Mo ratios that we observed are in accord with those found in a recent study of reclaimed coal spoils in western North Dakota (Bauer et al. 1976). In mine areas where molybdenosis may be a potential problem, wholesome pasturage can be established by avoiding molybdenum-accumulating plant species, or by minimizing access to the fresh forage, which can cause greater injury than properly cured hay (Barshad 1948; Miller et al. 1970). Molybdenum-induced Cu imbalances in the diet may be corrected by treating the livestock with either copper sulfate or copper glycinate, although the latter treatment can produce undesirable side effects.

It may be difficult to prevent the development of hazardous geochemical environments in some surface-mining operations. But with the proper management of reclaimed areas, mining and agriculture can be compatible.

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