Pollution by toxic metals on agricultural soils

SIR—We are concerned with the recent suggestion of Peter Moore[1] that there could be recuperative strategies for continuing agriculture on polluted soils rather than focusing on preventing the contamination of sewage sludge at source. Although use of the less contaminated sewage sludges produced in most rural areas will lead to few problems with metals, the difficulty is that most of the sludge to be disposed of each year comes from conurbations and is invariably contaminated with zinc, cadmium, copper, nickel, chromium and lead. Only with more stringent control over effluents from industry could the problem of sludges from cities be substantially reduced.

Metals are not removed from soil by normal cropping nor are they leached from near-neutral topsoils. A maximum of only 0.5 per cent of the amount of each of six metals accumulated in a sludge-treated soil is removed after 20 years of harvesting[2]. For all practical purposes, once metals are added to soil they remain there for thousands of years.

Certainly in the case of elements such as copper, little is absorbed from the soil by most plants unless very high concentrations are present, and as Moore suggests sheathing mycorrhizas are important in preventing metal uptake in very heavily contaminated soils. But not all potentially toxic elements behave in the same way; in particular cadmium is more readily absorbed from the soil and therefore is the element of greatest concern in food chains. There is no evidence of reduced cadmium uptake by plants infected with mycorrhizas. Furthermore, vesicular-arbuscular mycorrhizas, which infect major crop plants, actually increase metal uptake by plants[3]. Some other crop species are completely non-mycorrhizal, so the proposed[1] protection mechanism could not operate.

It is unlikely that the microbial population of the soil will be the sole solution to avoidance of metal toxicities. We have shown[4] that toxic effects of metals on *Rhizobium* caused complete suppression of symbiotic nitrogen fixation and reduced yields of clover by 40 per cent in the field. It appears that high metal concentrations cause loss of symbiotic plasmids in *Rhizobium*, leading to a lack of ability to nodulate the host plant[5]. Heavy-metal contamination may also halve the size of the microbial biomass[6] and prevents growth and nitrogen fixation by blue-green algae[7]. These effects occur at concentrations of metals close to the European limits[8].

Because toxic metals will persist for so long, the problem is not transient and could have widespread implications. This is particularly true for land taken out of agriculture. To maintain plant cover, such land will be dependent on biological fixation of nitrogen and cycling of nutrients through the microbial biomass. Surely there is a case for increased stringency in the guidelines for environmental protection, rather than advocating the increased application to land of sewage sludges contaminated by industry, until we know more about long-term effects of metals on microbial processes in the soil.

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Estimating the Maunder minimum from auroral data

SIR—Some of the recent papers concerning the solar activity in the seventeenth and eighteenth centuries infer that auroral observations can be used to provide new evidence for the solar minimum described by Maunder[1]. For example, Eddy[2,3] has suggested that auroral data may be used to provide a conclusive proof of this particular solar period.

An examination of historical sources, however, shows that such a premise cannot be accepted. Although the catalogue of Fritz[4] is certainly invaluable, many other sources must be considered[5].

A collection of available auroral observations during the second half of the seventeenth century is given in the table. It shows that there is insufficient evidence for a minimum of auroral activity during 1645–1715. There are only a few years during which no aurorae were recorded, and some of these fall into times of solar minimum, when scarcely any aurorae at all are seen in middle latitudes. Therefore the absence of auroral observations during 1645–1715 is not conclusive evidence for a general minimum of solar activity during this period. Furthermore, the frequency of aurorae during 1645–1715 shows the same characteristics as those seen in other long-term observations from middle latitudes (50–55 °N). From records for 1882–1965 the average number of aurorae every year is one to five, depending on the solar activity and solar cycle[5], and also on the attention paid to them by observers. This is also consistent with the period of the Maunder minimum (see table).

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Auroral data in central Europe 1645–1707

Year	Number of aurorae	Year	Number of aurorae	Year	Number of aurorae
1645	2	1666	3	1687	1 (2?)
1646	3 (4?)	1667	0	1688	1?
1647	0	1668	1?	1689	0
1648	5 (6)	1669	0	1690	?
1649	2	1670	2 (3?)	1691	0
1650	1	1671	1	1692	1 (3?)
1651	2	1672	1 (2?)	1693	?
1652	1 (3?)	1673	1	1694	?
1653	2	1674	0	1695	2 (3?)
1654	4	1675	0	1696	1 (3?)
1655	1	1676	3	1697	1
1656	0	1677	3	1698	?
1657	4	1678	1	1699	?
1658	2	1679	0	1700	0
1659	0	1680	3 (4?)	1701	0
1660	2	1681	3	1702	2
1661	4	1682	4 (5?)	1703	0
1662	3	1683	2 (3?)	1704	4
1663	3	1684	1	1705	2
1664	3	1685	1	1706	1?
1665	4	1686	5	1707	15