condensed in the expanding ejecta. To distinguish light echoes from light generated by the ejecta, measurements of the angular extent of the emitting regions are needed. Reflections of the flash off interstellar material in the foreground several hundred light years from the supernova can create a 'phantom nebula'. Such nebulae can appear to expand at velocities far exceeding the speed of light and are similar to the 'superluminal expansions' of extragalactic radio sources.

The phantom-nebula effect, which provides an elegant proof of the existence of interstellar clouds, has apparently been confirmed for SN1987A by recent photographic observations[16] (Fig. 2). Spectra[17,18] show that light from newly developed arcs 30 and 50 arc seconds away from SN1987A is identical to light emitted by the supernova shortly after its eruption a year ago.

Thermal light echoes caused by direct heating of, or reflections off, pre-existing material from the progenitor will be only an arc second across at present, whereas thermal emission from dust condensing in the ejecta will occur on spatial scales about 30 times smaller. The presence of pre-existing gaseous material has been detected by optical spectroscopy[19]. A spectacular visual brightening of the supernova could occur in several years when the blast wave runs into material previously ejected during the precursor's supergiant wind[20]. Such re-explosions could explain several reported re-appearances of historical supernovae. Secondary infrared thermal echoes could also result from this interaction[4]. □

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Agricultural ecology

Essential elements from waste

Peter D. Moore

THE disposal of human sewage raises ecological problems which are still far from being solved. Sewage sludge, a potentially toxic waste, must be removed from the centres of population where it is produced, rendered harmless and disposed of, often by incineration or by dumping as a land fill. But sewage is also a rich source of many of the elements required for crop production, like nitrogen and phosphorus, which are acquired only at great energetic and economic expense. Its organic content could provide the soil conditioner currently supplied by peat and thus contribute to the conservation of the world's declining wetlands. But there is a drawback. Other toxic components of sewage, particularly heavy metals, present a barrier to its widespread use. Recent work in arable agricultural systems in the United States[1], and in grasslands in Britain[2], show that the problems are not, however, insuperable: mycorrhizal fungi could provide a way forward in this important area of agricultural and ecological research[3].

Day and Thompson[1] conducted experiments in Arizona to test the efficacy of dried sewage sludge as a replacement for conventional fertilizers in the cultivation of wheat. Over three years they supplied different varieties of wheat crops with the recommended fertilizer levels for Arizona soils (mainly nitrogen and phosphorus, as potassium is considered to be adequate in these soils). At the same time, they applied dried sewage with nitrogen levels equivalent to those in the recommended fertilizers, and they also applied a nitrogen–phosphorus–potassium (NPK) treatment to match the sewage sludge. They find no difference in yield between wheat varieties, but all cultivars produce plants with higher yield in the sludge treatment or with the equivalent levels of NPK. So the sludge is an effective alternative to, and even an improvement on, conventional fertilizer treatments. The heavy-metal content of the grain is significantly greater in the sewage treatment for zinc, lead and nickel, but no significant differences were recorded for cadmium or copper. The levels recorded (45.3, 4.5 and 22.4 mg kg^{-1} for zinc, lead and nickel, respectively) are regarded by the authors as "not excessive". But the grain produced is intended for livestock feed and one needs to know more about the long-term accumulation effects in the food chain.

Heavy-metal accumulation can take place not only in food chains, but also in the treated soils, and long-term monitoring of soil levels is clearly needed both in arable and pastoral trials involving sewage treatment. Davis and co-workers[2] are concerned with pasture soils in Britain, where about 20 per cent of the sludge used in agriculture is applied as a dressing to permanent pasture. In a four-year experiment on both calcareous and neutral soils, they find that, on average, 87 per cent of the added heavy metal component becomes concentrated in the upper 5 cm of the soil. In the case of zinc, over the four-year period 94 kg ha^{-1} were added in the sludge, which results in an increase of 83.5 mg kg^{-1} in the concentration of zinc in the top 10 cm of soil. The ryegrass on the site takes up surprisingly little of this load. Less than 2 kg ha^{-1} of the added zinc is taken up into the pasture grass (under 2 per cent of the zinc added in sludge).

One possible source of protection of plants from excessive heavy-metal uptake is the fungal component of mycorrhizas[3]. The role of these symbiotic associations in the accumulation of scarce nutrients to the benefit of the host plant has long been recognized, but they may also play a part in the protection of plants from undue loads of potentially toxic elements. Fruiting bodies of some of the fungi involved in mycorrhizas accumulate heavy metals on contaminated soils, and there is some evidence that the fungal mycelium of the heather (*Calluna vulgaris*) mycorrhiza acts as a filter for heavy metals[4]. Colpaert and van Assche propose[3] that there are heavy-metal-tolerant strains of ectomycorrhizal fungi in such instances, and demonstrate the capacity of some fungal strains to grow well even at zinc concentrations of 1 mg g^{-1} (considerably higher than the concentrations recorded in the pasture-soils experiment). The culture and use of such strains could improve the soil/plant barrier for heavy metals in commercially important plant species and facilitate the development of sewage-based fertilization systems of agriculture.

One problem remains for the pastoralist. How can the grazing animal be prevented from eating contaminated soil? Perhaps, as Fleming suggests[5], pasture soils need to be ploughed occasionally to mix metals in the soil and prevent their concentration in the surface layers. □

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Erratum

IN the article "Action at a distance" by Neville Symonds (*Nature* **333**, 18–19; 1988), Fig. 1 should have been credited to M.G. Surette, S.J. Buch and G. Chaconas (*Cell* **49**, 253–262; 1987). □