Self-cleaning of the Gulf

SIR — It has been calculated that the Arabian Gulf is charged yearly with 160,000 tons of oil arising from legal as well as illegal activities[1]. Nevertheless, the deliberate release of oil by the Iraqi forces during the occupation of Kuwait (2 August 1990–26 February 1991) has left the Gulf environment confronted with the greatest single oil pollution event known. On 19 January 1990, the Iraqi forces released into the Gulf from Mina Al-Ahmadi oil terminal about 500,000 tons of crude oil. This oil has drifted from the Kuwaiti coasts, and has in part severely polluted about 770 km of the Saudi Arabian coasts. Thus, for example, the coast of Jubail, a Saudi research station about 200 km south of the Kuwaiti borders, has become covered with up to 20 kg m^{-2} oil, and the free rock surfaces with up to 1.4 kg m^{-2} (ref. 2). This research station falls within the coastline sector reported to be most polluted with oil[3].

Weekly inspection of the Jubail coast between May and December 1991 has revealed no substantial improvement except for one interesting phenomenon, the intensive appearance of blue-green microbial mats over oil layers. These mats now cover the regularly inundated lower part of the oiled intertidal zone. Strikingly, the microbial mats are intimately associated with oil, so that oil-free areas are also free of such mats. Subsequently, the mats with the strongly adhering oil layers are subjected to tearing and dissection into irregular scales of varying dimensions, about 10–30 cm in diameter. The whole area appears as if it has just been subjected to farming management (see figure).

Scaling of microbial mats on oily coastline

All forms of higher life on the oiled beaches have been seriously affected by the oil pollution. We have observed that animals such as *Ocypode* and *Cleistostoma*, once common inhabitants, are absent or dead, and their underground channels in the coast are full of oil. It appears that the natural cyanobacterial grazers have been severely affected by the oil. Consequently, the cyanobacterial mats, which are not nutrient-limited, have had the chance to flourish. In this context, Readman *et al.*[3] noted that subtidal sediments were poor in hydrocarbons, and the near-shore animals, for example, molluscs and fish, survived.

We believe that the intensive growth of blue-green microbial mats on the top of oil in Saudi coasts is the first sign of self-cleaning activity in this polluted region. These microbial associations appear to be the only living things in this environment.

We have analysed the composition of the mats and find that they are associations of photosynthetic and nonphotosynthetic microorganisms. In most localities, one filamentous cyanobacterium, *Microcoleus* sp., is predominant, making up about 65% of the biomass volume. The mats also contain *Spirulina*, various diatoms and small numbers of many other unidentified green microorganisms. In a few regions, the predominant microorganism was another chromogenic (red), unicellular cyanobacterium which we have not yet identified.

One characteristic of these predominant cyanobacteria is that they produce large amounts of mucilage in which the cells and filaments are embedded. Whether these photosynthetic organisms can degrade oil is still under investigation. Only a little is known about the ability of photosynthetic microorganisms to biodegrade hydrocarbons[4]. However, we have found embedded in the mucilage, intimately associated with the cyanobacteria, up to one million cells per gram of fresh mat of organotrophic bacteria capable of utilizing crude oil and individual *n*-alkanes as sole sources of carbon and energy. There is no information in the literature on the occurrence of such mats before the oil catastrophe. However, cyanobacterial mats containing *Microcoleus* sp. as a minor constituent have already been recorded in the unpolluted coast of Abu Dhabi[5], yet there is no mention of oil-degrading bacteria in such mats.

The presence of such large numbers of oil-degrading bacteria immobilized within the mats suggests that oil degradation is being stimulated by nitrogen leaching from the cyanobacteria. Immobilizing oil-degrading bacteria within the cyanobacterial mucilage protects them from being washed out to the open sea and, in addition, provides them with oxygen from the photosynthetic partner. Oxygen is essential for hydrocarbon biodegradation. Laboratory studies have shown that calcium alginate-immobilized microorganisms maintain their alkane-degrading activity[6,7], so it is possible that complex microbial associations can efficiently biodegrade the oil pollutants.

Finally, the mats we describe here have not been found to be associated with earlier oil spills elsewhere, and appear to be unique to the extreme environment of the Gulf.

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1. Oostdam, B. L. *Mar. Pollut. Bull.* **11**, 138 (1980).
2. Höpner, Th., Berthe-Corti, L., Harder, H. & Michaelsen, M. *Erdöl Kohle* **44**, 197 (1991).
3. Readman, J. W. *et al. Nature* **358**, 662 (1992).
4. Cerniglia, C. E., Gibson, D. T. & van Baalen, C. *J. gen. Microbiol.* **116**, 485, 495 (1980).
5. Golubic, S. in *Environmental Evolution: Effects of the Origin and Evolution of Life on Planet Earth* (ed. Margulis, L.) 103–130 (MIT, Cambridge, Massachusetts, 1992).
6. El-Aassar, S. A., Omar, S. H. & Rehm, H.-J. *Appl. Microbiol. Biotech.* **29**, 442 (1988).
7. Heinrich, M. & Rehm, H. J. *Eur. J. appl. Microbiol. Biotech.* **11**, 139 (1981).

Patch production by cattle

SIR — In his News and Views about herbivore influences on grassland heterogeneity, Moore[1] implies a relative poverty in "the patchy environment created by the leaky cow". However, he does not consider the East African grasslands, which provide one of the richest examples of spatiotemporal heterogeneity created by herbivores, and support in turn a unique density and diversity of grazing mammals. The 45,000-km^2 Serengeti Ecological Unit has 35 wild ungulate species, of which 15 coexist in superficially similar niches. In addition, pastoralists like the Maasai have grazed their herds here for more than 2,000 years. In 1960, the Maasai were excluded from the 15,000-km^2 Serengeti National Park, but they continue to use that part of the Serengeti Ecological Unit with the highest seasonal herbivore density and diversity, the 8,000-km^2 Ngorongoro Conservation Area. Grassland heterogeneity in this joint land use area still owes as much or more to the