The geological environment

Links with the human dimension

Jane Plant & Henry Haslam, *Keyworth*

Recent population growth and economic advances give increasing cause for concern about the state of the environment. Concern that human activities are unsustainable has led to statements like that of the World Commission on Environment and Development (the Brundtland Commission) that humanity should ensure that 'it meets the needs of the present without compromising the ability of future generations to meet their own needs.' The 1992 Rio Declaration on Environment and Development called for states to 'reduce and eliminate unsustainable patterns of production and consumption'.

Over aeons, the Earth has been transformed by a complex interplay of physico-chemical and biological processes from a hot, dry ball of dust spinning through space more than 4500 million years ago into a planet with a cool and varied surface environment, where abundant water and an oxygenated atmosphere are able to support complex and diverse life forms. Over time, Earth processes have also led to the accumulation of metallic, energy, industrial and construction minerals, which are used by man to provide shelter and food and to support an ever-increasing material standard of living. The speed and scale of man's activities, however, are such that they are causing serious damage to mechanisms which have evolved over a very long period of time, and the fabric of life-support systems is beginning to unravel.

Today's industrial society depends on the ready availability of metallic, non-metallic and energy minerals. The concept of sustainable development requires that the most efficient and effective use is made of minerals, to maximise the value of the resource and minimise waste and environmental impact. Full life-cycle analysis in relation to economic well-being is therefore essential. The principle of sustainability requires that the products of fossil fuel combustion and nuclear fission should be returned to the geosphere, and methods of disposing of carbon dioxide into defunct oilfields and nuclear waste into safe repositories in bedrock should be thoroughly researched.

Full life-cycle analysis should also be applied to land. Land contaminated by previous industrial use, including mining, should be restored and re-used. Modern industry seeks to minimise contaminating discharges, and planning permission for the extraction of minerals should be conditional on land being restored to a state suitable for beneficial after-use, in consultation with local communities. Potential uses include leisure activities, agriculture, nature conservation and landfill. In the case of landfill, the local geology affects the behaviour of contaminants, the extent of natural attenuation, and thus the impact on the environment. Geochemistry, hydrogeology, microbiology and engineering geology have an important part to play in minimising environmental impact.

Contaminated land is of increasing concern throughout the world, but too often sites are considered in isolation. It is important that human-induced heavy-metal contamination should be assessed in the context of natural levels, as recorded by regional geochemical baseline surveys like those carried out by the BGS and other national geological surveys.

A self-sustaining planet?

- The Gaia hypothesis, which takes the view that life, the environment and the planet are part of a single system, provides a realistic model for understanding the interactions between human activity and the many chemical, physical and biological processes that take place on the Earth's surface. Gaia forces a planetary perspective: it is the health of the whole planet that matters, not that of individual species or organisms.
- Natural processes, acting on a larger scale than human activity, can have a profound and long-lasting effect on climate.
    - There have been four major glacial to interglacial cycles since 450 000 years ago: some scientists predict that there will be a fifth glacial period in about 20 000 years' time.
    - Volcanic activity can result in the emission of large amounts of fine ash or dust together with volcanic gases which can rise to great altitudes and encircle the globe, causing lowering of global temperatures. Conversely, volcanoes can emit large amounts of carbon dioxide, adding to the Earth's store of greenhouse gases which increase global warming.
- Natural processes can both cause and mitigate the effects of acid precipitation.
    - A significant proportion of acid precipitation is caused by volcanic gases.
    - The effects of acid deposition are buffered in soils rich in calcium and magnesium, such as those developed over limestone, while soils deficient in these elements, such as those developed over granites or slates, release aluminium ions which are potentially toxic to humans, animals and crops.

It has been estimated that approximately 65 per cent of the total dose of ionising radiation received by the average UK citizen is from gamma rays and radon released naturally from rocks and soils, compared with one per cent from all non-medical artificial sources. The BGS is engaged in the mapping of radioactivity and the preparation of radon-potential maps, to enable the risk to human health to be minimised.

"... Earth processes have also led to the accumulation of metallic, energy, industrial and construction minerals, which are used by man to provide shelter and food and to support an ever-increasring material standard of living ..."

Serious health problems for man and animals can be caused by chronic deficiencies of micronutrients such as iron, selenium and iodine, which tend to be extracted from the soil by modern agricultural practices and the failure to recycle waste back to the land.

Human activity can cause erosion over large areas. Excavation and building on steep terrain can induce landslides and ground failures, possibly resulting in substantial loss of life. Underground mining has often been the cause of subsidence, and mine tips are prone to landslip. In the coastal zone, strategies are being developed to protect against marine erosion and flooding. The protection of cliffs from erosion may save communities and valuable land, but the disruption to the natural system of sediment movement can reduce deposition elsewhere, resulting, for example, in the disappearance of sand beaches. Offshore, the dredging of sand and gravel for use by the construction industry has led to concerns about the effects on shoreline stability, the degradation of marine habitats and reduced productivity of fisheries.

About 70 per cent of the Earth's surface area is covered by water, but most of it is salt water. More than 95 per cent of fresh water is groundwater and less than five per cent is surface water. Increasing demand for water for agriculture, industry and domestic consumption is leading to over-extraction of groundwater and salination of water supplies.

Waste disposal: natural analogues

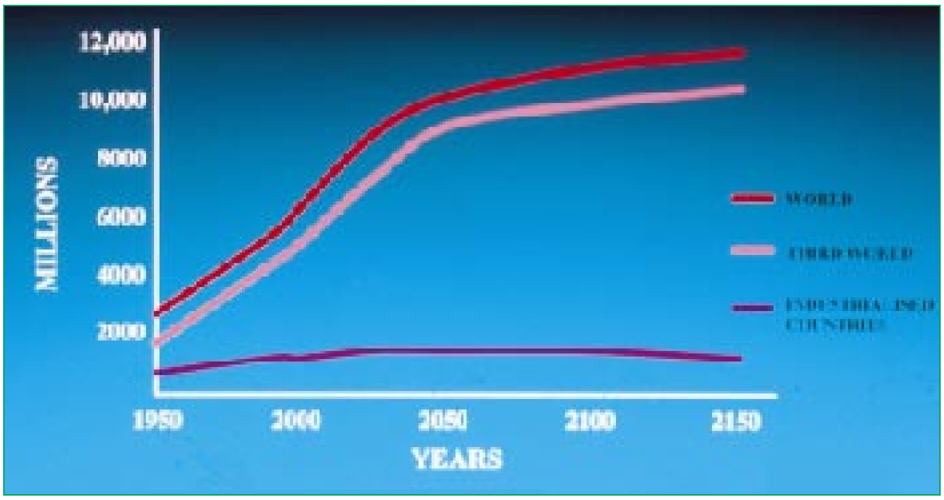
Natural analogues provide an opportunity to study how hazardous substances have moved and how far their movement has been inhibited by natural barriers over periods of millions of years.

- Metal-rich deposits on the ocean floor provide natural analogues to inform decisions about deep-sea dumping of metallic wastes.
- Some uranium ore deposits in north Africa are so radioactive that they formed natural nuclear reactors. Understanding such ore deposits as natural analogues of nuclear waste repositories is crucial to developing procedures for the safe containment of nuclear wastes.

Groundwater in its natural state is generally of excellent quality because rocks act as filters. However, population pressure and intensive agriculture are leading increasingly to contamination by pathogens and also, since the industrial revolution, by chemical contaminants from industrial production and waste-disposal sites. The environment is also threatened by abandoned mine workings and by the rebound of water tables in contaminated urban areas where water is no longer extracted. An improved understanding of hydrogeology is essential in the assessment of the vulnerability of aquifers to contaminants and in the responsible management and protection of potable water resources in Britain and elsewhere.

Sustainability requires a non-declining capital stock (the aggregate of produced, human and natural capital), including raw materials, waste receptors, landscape and amenity assets, accompanied by economic efficiency. It also involves fairness across different interest groups. Present population levels and life styles require that every part of the globe should be subject to a sustainable management regime: we can no longer afford to destroy tracts of land and leave it to nature to rehabilitate them.

The BGS and other national geological surveys throughout the world acquire and maintain authoritative, systematic, quality-assured information on geology, geophysics, geochemistry, hydrogeology and mineral resources, onshore and offshore. This information is recorded in digital form and can be interacted using sophisticated computer technology. Such data presented on Geographical information Systems or 3D or 4D models can be used to inform policy and to help to achieve economic development while sustaining the environment. They can be made available in an attractive and easily understood form, empowering decision makers and the wider public to improve their understanding of their environment and to contribute to improving it.



Estimated and projected world population, medium-fertility (Source: UN, 1992).