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Earth and health -

building a safer environment

Earth sciences for society

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Prospectus for a key theme of the International Year of Planet Earth

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Earth Sciences for Society

What is this brochure for?

This brochure is a prospectus for one of the main scientific themes of the International Year of Planet Earth 2005-2007.

It describes, in terms accessible to the informed layperson, why the research that the Year hopes to support under this theme is of such vital importance to our understanding of the Earth System, and to society at large.

It was written by a panel of world experts, assembled by the Science Programme Committee for the International Year.

To find out more...

Every science theme will have a prospectus like this one. To find out about the other research themes being pursued under the International Year, please consult www.esfs.org

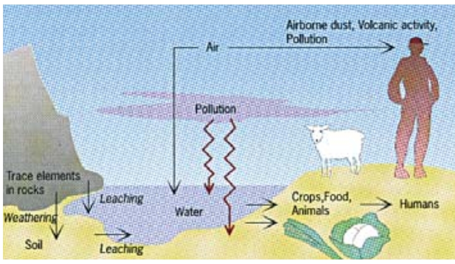
What to do next...

If you are a scientist wishing to register initial interest in possibly making a research proposal under this theme, please go to www.esfs.org and download the appropriate Expression of Interest (Science) form, and follow the instructions on submitting this to the International Year. (If you cannot find such a form, it means that it is not ready – please keep visiting the site.)

The relation between rocks, minerals and human health has been known for centuries

Introduction

Geology may appear remote from human health. However, rocks are the fundamental building blocks of the Earth's surface, full of important minerals and chemical elements. Most elements are taken into the human body in air, food and water. Rocks are broken down by weathering processes to form the soils on which crops and animals are raised. Drinking water travels through rocks and soils as part of the water cycle, and much of the dust and some of the gases contained in the atmosphere are of geological origin.



Earth and Health, or "Medical Geology", is concerned with the relationship between natural geological factors and human and animal health - as well as with improving our understanding of the influence of environmental factors on the geographical distribution of health problems. Medical Geology brings together Earth scientists and medical/public health researchers to address health problems caused or exacerbated by geologic materials (rocks, minerals and water) and processes - such as volcanic eruptions, earthquakes and atmospheric dust.

"The right dose differentiates a poison and a remedy" - Paracelsus

Medical geology is a subject that is not so much emerging as "re-emerging". The relation between rocks, minerals and human health has been known for centuries. Ancient Chinese, Egyptian, Islamic, and Greek texts describe the many therapeutic benefits of various rocks and minerals, as well as the many health problems they may cause. More than 2000 years ago Chinese texts described the use for medical purposes of 46 different minerals.

The basic law of toxicology was first laid down by Paracelsus (1493-1541): "All substances are poisons; there is none which is not a poison. The right dose differentiates a poison and a remedy". Thus, negative biological effects can result from both increasing and decreasing concentrations of various trace elements.

"Direct links between geology and health are provided by the food chain and by inhalation of atmospheric dusts and gases"

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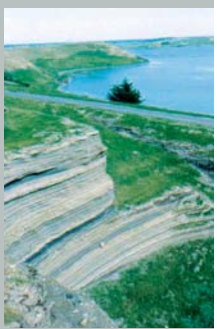


Earth and Health - a priority in the International Year of Planet Earth.

- Many diseases and conditions can be traced to sources in natural Earth materials.
- There is an urgent need to apply geochemical and mineralogical techniques to pathology and the study of internal pathways. Both beneficial and harmful aspects of the links between Earth materials and human health need to be more fully understood. In particular, the relation between human health and excesses or deficiencies of elements, ions and key micronutrients (e.g. iodine, selenium, iron, arsenic, radon and many others), as well as globally widespread but less well-defined agents (e.g. quartz), need to be highlighted.
- Scientists will benefit from the experience that they will gain in bridging gaps and breaking down barriers between the components of this intrinsically interdisciplinary and socially relevant scientific field. The partnership will involve Earth scientists, medical researchers, pathologists, toxicologists, veterinarians, epidemiologists, medical geographers, veterinary scientists, dental scientists and wildlife managers.
- Research in such relevant specialisms will require close integration if there is to be significant progress. A close working relationship between the Earth science community and professionals in community health will also be needed.

The Earth and health - some key questions

- Can we identify the environmental causes of known health problems and, in collaboration with biomedical/public health researchers, seek solutions to prevent or minimize these problems?

Working together, Earth and health scientists bring an arsenal of valuable techniques to bear upon health problems arising from geological materials and processes. Although some of these techniques may be common to many disciplines, practitioners in each may well apply them in quite different ways - or from distinctive viewpoints. This can be both challenging and illuminating. For example, the environmental health community uses a wide array of tools and information (databases) to address vector-borne diseases and to build models of pollution dispersion in surface and ground water. By integrating Earth science and health professionals we can find solutions to environmental causes of health problems.

Clouds of volcanic ash can pose major global health risks

Soils, sediments and water

- How can we identify geochemical 'highs' and 'lows' in soils, sediments, and water that may impact on health - and what are the critical links between these and the health of humans and animals?

This linkage of excess and deficiency can be illustrated by many examples.

Volcanism and related activities bring metals and other elements to the surface from deep within the Earth. Volcanic ash introduces new elements into the environment, and may increase toxicity in the food chain. Clouds of volcanic ash can pose major global health risks, causing both short and long term health problems from minor lung irritation to silicosis.

Earthquakes also threaten health both directly and indirectly, but indirect effects are of most concern. Many such problems result from earthquake-induced landslides that remobilise elements and other potential risk agents such as the fungus known to cause "valley fever".

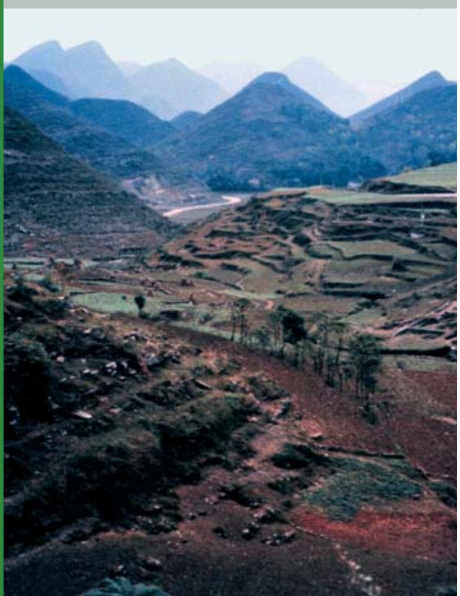
High levels of the element arsenic in drinking water cause serious health problems for many millions of people in Asia. Improving the situation requires close study of the source rocks from which the arsenic is being leached, as well as the conditions under which the arsenic is being mobilised. Answers to these and related questions are vital if public health authorities are to identify aquifers with similar characteristics, so that populations at risk from exposure can be more accurately determined.

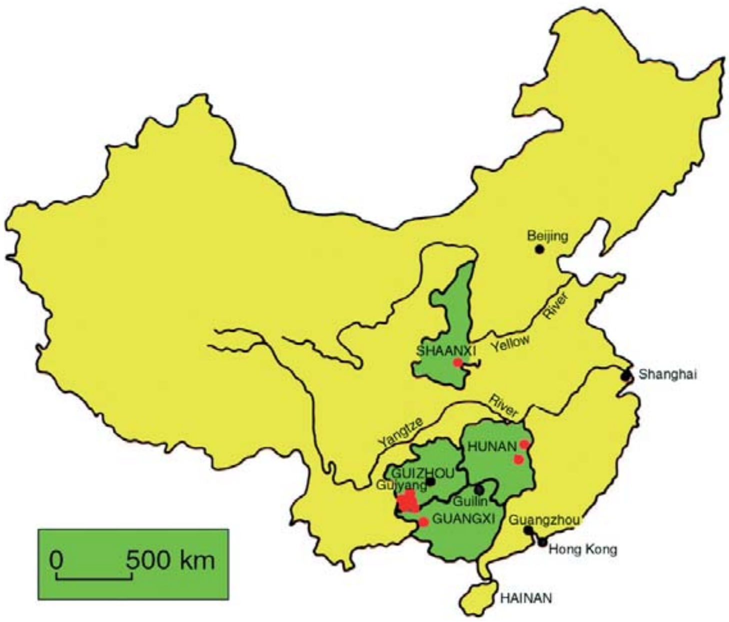
Earth scientists can identify the elements present in (or absent from) our environment

Another element, radon, is an invisible, colourless, odourless radioactive gas that seeps easily through soil and may leak into houses. It is the most significant potential health threat from natural radiation. The most common effect associated with radon exposure is lung cancer.

Radon and arsenic are examples of dangerous elements. Other elements in rocks and water are vital for a healthy life, and the lack of some elements may have severe health effects. Communities in upland areas were once commonly afflicted by iodine deficiency, because iodine is easily leached from thin soils in exposed areas with high rainfall. The heart-muscle condition known as Keshan Disease is another example. Known only since the early part of the 20th Century from NE China (map), this disease is caused by a lack of the element selenium. A geological explanation was suspected in the 1960s, and very low selenium concentrations in bedrock, soils and natural waters were later discovered. Treatment of patients with supplementary selenium has since proved a great success.

Incidence of Keshan Disease (degeneration of the heart muscle: chronic cardiomyopathy) and Kashin-Beck Disease (bone ossification: endemic osteoarthropathy) in China. Both diseases have been attributed to low levels of the element selenium in soil and food. (After Derbyshire, E. 2001. Geological hazards in loess terrain, with particular reference to the loess regions of China. Earth Science Reviews 54: 231-260.)





Earth scientists can identify the elements present in (or absent from) our environment. The critical links are then identified in collaboration with the health professionals.

Clearly, *Earth and Health* can have close links with other major research themes within the *International Year of Planet Earth* (Prospectus 1) - notably *Climate* (Prospectus 5), *Megacities* (Prospectus 7) *Resources* (Prospectus 6).

Arsenic - a burning issue

Chronic arsenic poisoning affects people in southern China, patients affected exhibiting typical symptoms including hyperpigmentation, hyperkeratosis, and Bowen's disease. Unlike other communities with endemic arsenic poisoning, their problem is not with the drinking water, but with the chilli peppers.

In parts of Southern China chilli peppers are commonly dried over open coal-burning stoves that use local coal that is very high in arsenic. While fresh chilli peppers contain less than one part per million (ppm) arsenic, those dried over coal fires may exceed 500ppm. Arsenic may also come from other tainted foods, by ingesting dust (see below), and from breathing in air polluted by coal burning. Collaboration can help in identifying the links between bedrock, soils, drinking water and food, thus increasing the quality of life for millions of people.

Arsenical keratosis of the hands

BEN hope

Balkan endemic nephropathy (BEN) is an irreversible kidney disease also thought to be due to coal. Known only from rural parts of the lower Danube River, several thousand people currently suffer from BEN. Certain toxic organic compounds in drinking water sourced in low-grade coal (lignite) rocks may be responsible, but nothing is yet proven. Thus BEN poses a challenge to scientists working in disparate disciplines (medicine, epidemiology, geology, hydrology, geochemistry).

There are also close links here with the International Year's *Resources* theme (Prospectus 6).

Fluorine and health

Fluorine is an essential element in the human diet. Lack of it has long been linked to tooth decay - hence the effectiveness of fluoride toothpaste. Some countries also add fluorine to water supplies (to boost naturally low concentrations).

However the detrimental effects of excessive doses (associated with consumption of fluoride-rich groundwater) are also well documented. Dental fluorosis is an irreversible condition caused by excessive ingestion of fluoride during the tooth-forming years. It is the first visible sign that a child has been overexposed to fluoride. Fluoride causes dental fluorosis by damaging the enamel-forming cells, called ameloblasts. The damage to these cells results in a mineralisation disorder of the teeth, whereby the porosity of the enamel is increased and the mineral content decreased. In extreme cases, the skeleton is also affected (skeletal fluorosis).

Large populations in the developing world suffer the effects of chronic endemic fluorosis. More than 200 million people worldwide are thought to be drinking water with fluoride in excess of the WHO guideline value. The health problems caused by fluorine released into the air by burning of domestic coal are also extensive.

The International Year

Initiated by the International Union of Geological Sciences (IUGS) in 2001, the proposed International Year of Planet Earth was immediately endorsed by UNESCO's Earth Science Division, and later by the joint UNESCO-IUGS International Geoscience Programme (IGCP).
The main aim of the International Year - to demonstrate the great potential of the Earth sciences to lay the foundations of a safer, healthier and wealthier society - explains the Year's subtitle: Earth sciences for society.

How will it work?

To achieve maximum political impact, the IUGS-UNESCO team aims to have the International Year proclaimed through the UN system, targeting 2006 as the Year itself. Its ambitious programmes cannot, however, be implemented in twelve months. We expect the Year's activities to begin in 2005 and culminate in 2007.

Science programme

A panel of 20 eminent geoscientists from all parts of the world decided on a list of nine broad science themes - Groundwater, Hazards, Earth & Health, Climate, Resources, Megacities, Deep Earth, Ocean, and Soils.

The next step is to identify substantive science topics with clear deliverables within each broad theme. A 'key-text' team has now been set up for each, tasked with working out an Action Plan. Each team will produce a text that will be published as a theme prospectus like this one.

A series of Implementation Groups will then be created to set the work under the eight programmes in motion. Every effort will be made to involve specialists from countries with particular interest in (and need for) these programmes.

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Corn dried over unvented ovens burning high-fluorine coal is the probable cause of the extensive dental and skeletal fluorosis in southern China, affecting more than 10 million people. The problem is compounded by the use of clay as a binder for briquettes (the clay in question being a high-fluorine residue formed by intense leaching of a limestone).

Working together, health professionals and geoscientists can materially help people suffering the health effects of fluorine (and other elements).

Geophagia - biting the dust

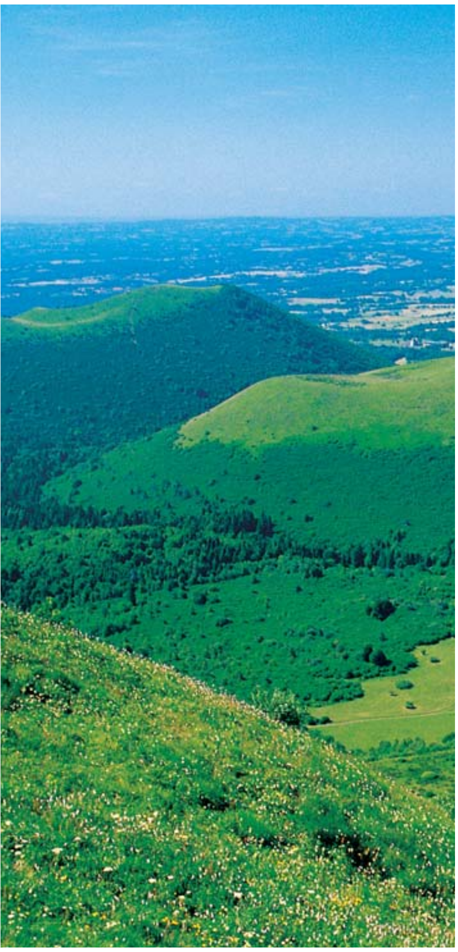
The deliberate eating of soil is a common practice in members of the animal kingdom, including humans, and is known from many ancient and rural societies. Geophagia (also called "geophagy") is considered by many nutritionists to be either a learned habitual response (eating clays and soil minerals to reduce the toxicity of various dietary components) or as an inbuilt response to nutritional deficiencies resulting from a poor diet. Geophagy is attracting renewed and serious interest from researchers.

Future multidisciplinary research is likely to investigate a number of these issues, including soil ingestion as a supplier of mineral nutrients such as iron, or potentially harmful elements such as lead or radionuclides. This will involve quantitative work, leading to better understanding of the implications of soil ingestion for epidemiological studies and risk assessment.

Geopharmacy

We live in

a dusty world



The air we breathe

Atmospheric dust

We live in a dusty world; the dust that falls in our backyard (the ‘sink’) may have originated thousands of miles away (the ‘source’).

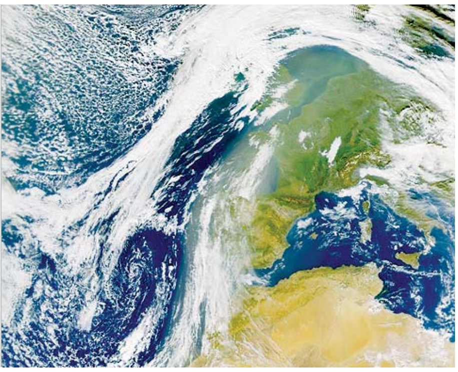
Dust is a global phenomenon. Dust storms from Africa regularly reach the Alps, and Asian dust outbreaks can reach California in less than a week, some ultimately crossing the Atlantic to Europe.

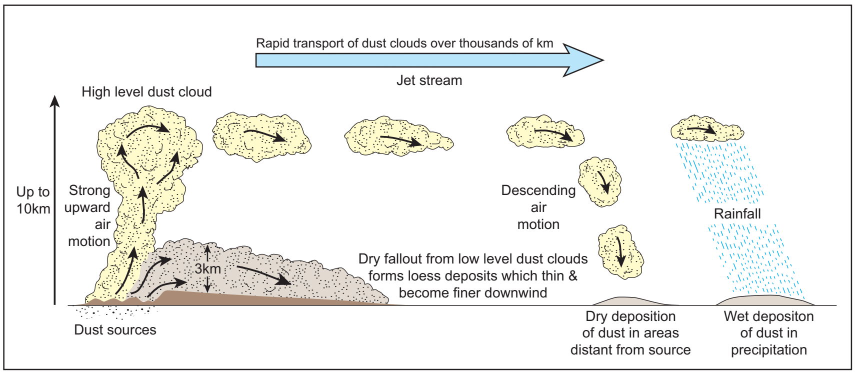
The ways in which mineral dust impacts upon life and health are wide-ranging. These include:

- changes in the planet's radiative balance (dust reflects heat and cools the planet)
- transport of disease bacteria to densely populated regions
- dumping of wind-blown sediment on pristine coral reefs
- general reduction of air quality
- provision of essential nutrients to tropical rainforests.
- toxic substances

Dust may be mobilised by humans and by nature. We mobilise dust when we disturb the land surface or strip it of its vegetation. Changing climatic conditions play a key role as natural changes occur in available moisture and wind speeds. Although vegetation exerts a critical control on dust mobility, vegetation itself is influenced by climate, human activity and other factors.

A better understanding of dust, including the processes that control its sources and transport as well as its impacts, is needed if its negative consequences are to be mitigated; identifying and controlling at least those due to human activities would be a good start.





Principal atmospheric pathways between dust sources and dust sinks, involving both dry and wet deposition modes. (After K. Pye 1987. *Aeolian Dust and Dust Deposits.* Academic Press, London, U.K.)

Very fine particles may penetrate deeply into the lungs

Photos: E. Derbyshire

How extensive is the health impact of global dusts?

Neither the precise nature nor the epidemiology of the health impact of natural atmospheric dusts (non-occupational lung disease) is known in any detail. Very fine particles may penetrate deeply into the lungs to cause silicosis, asbestosis and other lung conditions. The denser the dust concentration, the higher the rates of chronic respiratory disease and associated death rates.

Natural (non-occupational) silicosis was first reported in some Bedouin people in the Sahara Desert in the middle of the 20th Century, and has since been found in Pakistani farmers, Californian farm workers, Ladakh villagers, and Thar Desert residents (NW India), as well as in northern China. While little quantitative information on natural silicosis is available, studies showing an incidence of over 22 % of the population of some Ladakh villages and over 21% in people over 40 years of age in settlements in North China make it likely that the population affected in Asia is probably numbered in millions.

Will we be able to predict health problems arising from breathing dust, and how will this threat be mitigated?

Both land surface and atmospheric dusts will have to be more closely studied if we are to answer this question satisfactorily. On land, dust source and deposition regions must be identified, and the ways in which movement of dust (dust fluxes) have varied in the recent past and under various climatic conditions must be determined.

We still have much to learn about how dust is transported, as well as the influence of atmospheric dust on the Earth's radiation balance. Such work requires expertise in land surface processes, geochemical/isotopic 'finger-printing', analysis of past climates, remote sensing, and close investigation of atmospheric radiation and dynamics. Incorporating dust into climate models (from source to sink) will improve understanding and enable us to provide predictions on several time scales (weeks to centuries).

There are also close links with the *Hazards* theme of the International Year (Brochure 3)

Raising public awareness

How can we reassure the public over health problems arising from geological materials or processes?

Health problems arising from geological materials and processes are more common than most people believe. The health of an estimated 3 billion people all over the globe may be affected by geology. This is mostly unknown to the public. Information is of greatest importance not only for general public but also for doctors, health professionals, decision makers, and planners.
If geology is considered in health planning many negative health effects can be avoided.

Scientists in developed and developing countries will be brought together to address this global issue

How can links between developed and developing countries be established so as to provide solutions to common health problems?

Scientists in developed and developing countries will be brought together to address this global issue. One effective way of doing this is by running international short training courses. Such courses will be highly successful in sharing the most recent information on the relationship between metal ions, trace elements, and their impact on environmental and public health. Course contents include environmental toxicology, environmental pathology, geochemistry, geoenvironmental epidemiology, extent, patterns and consequences of exposures to metal ions, and analytical methods. Such activities will be extended to include research projects involving local scientists in the less developed countries, especially where there is a pressing need to tackle health issues arising from geology.

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