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ENVIRONEMENTAL GEOCHEMISTRY AND HEALTH - GLOBAL PERSPECTIVES

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Introduction

Rocks are the fundamental building blocks of the planet surface and different rock mineral assemblages contain the 92 naturally occurring chemical elements found on Earth. Many elements are essential to plant, animal and human health in small doses. Most of these elements are taken into the human body via food and water in the diet and in the air we breathe. Through the food chain and through the inhalation of atmospheric dusts and gases, there are direct links between geochemistry and health (Figure 1).

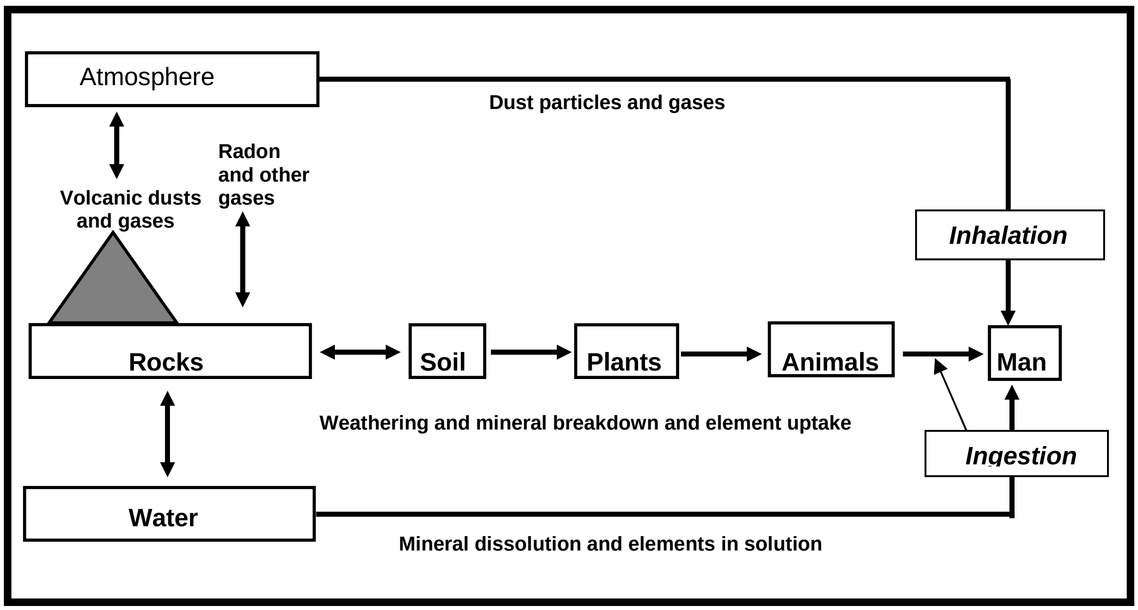

Figure 1. Simplified schematic diagram of the natural cycling of chemical elements from the geosphere into man.

Geochemists have been studying the links to health for over 50 years with growing importance in the last 20 – 25 years. There is increasing concern about the effects of chemicals on the health of man, animals and crops and the sustainability of the Earth's surface life support systems. There is also an awareness that man is influencing the environment at the global scale.

It is important to realise that these chemicals can be natural or anthropogenic in origin. A number of geochemical factors such as soil and water pH, organic matter content, Eh conditions and the chemical form or speciation greatly influence the mobility and bioavailability of both natural and man-made chemicals in the environment. An understanding of these factors is necessary to remediate problems effectively.

The 92 naturally occurring elements are not distributed evenly across the surface of the earth and problems can arise when element abundances are too low (deficiency) or too high (toxicity). The inability of the environment to provide the correct mineral balance can lead to serious health problems.

Geochemistry and Health

Low dietary intakes of iodine have been linked with a set of conditions known as iodine deficiency disorders (IDD). Iodine is involved in the processing of growth hormones in the thyroid gland and in most cases iodine deficiency manifests itself as an enlargement of the thyroid, a condition known as goitre. Iodine deficiency in pregnant mothers can also lead to cretinism and impaired brain function in children. The World Health Organisation currently estimates that over 1.6 billion people are at risk from iodine deficiency and that it is the single largest cause of mental retardation in the world today.

In China, selenium-deficient environments have been linked to a heart disease which results in damage and enlargement of the heart muscles and death. It was anticipated that highest disease incidence would occur in areas with lowest environmental Se. Recent investigations by the British Geological Survey (BGS) funded by the UK Department for International Development (DFID) demonstrated that highest disease incidence occurred in villages with the highest total Se content of soils (Figure 2). This is the opposite trend to that expected, but further geochemical studies showed that the organic matter content of the soil in these areas is a key control inhibiting Se bioavailability and uptake into local food crops.

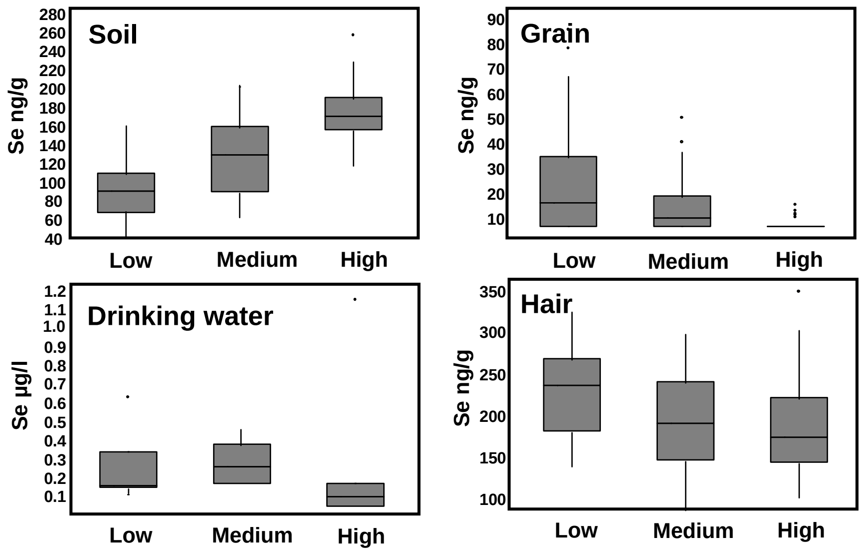

Figure 2. Box and whisker plots of 25th, 50th, 75th and 90th percentile total selenium concentrations in soil, grain (wheat), drinking water and hair samples in villages with low, medium and high disease incidence. Five villages were sampled in each disease incidence category. All villages lie in the low selenium belt, China.

Exposure and Bioavailability

In addition to understanding both natural and anthropogenic sources of harmful substances in the environment, it is also important to consider exposure and bioavailability. Bioavailability directly influences exposure and therefore the effect and risk of health detriments. Large quantities of a potentially harmful substance may be present in the environment, but if it is in a non-bioavailable form, the risk to health may be minimal.

Furthermore, a potential hazard only becomes a problem if there is an exposure route. This is clearly demonstrated by the current problems with arsenic in groundwater in Bangladesh. Inorganic arsenic is one of the oldest known poisons to man and causes damage to the skin and to internal organs leading to cancer and death. The potential hazard of high arsenic groundwaters has existed in Bangladesh for thousands of years but it is only in the last 20 - 30 years that groundwater has been extensively exploited and an exposure route established. It is estimated that 200 000 people have developed arsenic poisoning including skin and internal organ cancers, and that 20 – 30 million people are drinking water which exceeds the Bangladesh toxicity limit (0.05 mg/l).

Exposure pathways include diet (food, water, deliberate/inadvertent soil ingestion), dermal absorption and inhalation. In terms of ingestion, much emphasis has been placed on water, simply because it is an easy sample-type to analyse. However, soils and foodstuffs are likely to be far more important dietary contributors because the concentrations of potentially harmful substances in soils are much greater (parts per million) than in water (parts per billion). Whether soil ingestion is inadvertent or via the deliberate eating of soil known as geophagia, this exposure route should not be under-estimated.

Investigations carried out by BGS under the DFID aid programme into high cerium and low magnesium in relation to a heart disease, endomyocardial fibrosis (EMF), in Uganda revealed the importance of understanding exposure pathways. Studies revealed that the Ce content of soil is four times greater than that of foodstuffs and that the deliberate and inadvertent ingestion of soil is the dominant exposure route for Ce and many other elements in the Ugandan diet.

Studies of sources, exposure, bioavailability and risk are extremely complex and require a multi-disciplinary approach to problem solving. However, geoscientists have an important role in these issues. Hazards may be physical (including geological), chemical (including geochemical) or biological; exposure assessments may require nutritional, geochemical, mineralogical, biological and sociological information and determination of the health effects requires medical, sociological, epidemiological and chemical (including geochemical) knowledge.

Regulation of Potentially Harmful Substances (PHSs) – the need for Geochemistry

Clearly there is a link between the cycling of chemical substances through the natural environment and adverse effects on human health. These problems literally affect billions of people world-wide, many of whom are the poorest in society. Substances of particular concern include the heavy metals (such as copper, chromium, nickel, lead and zinc), selenium, fluoride, radioactive substances (natural and man-made) and persistent organic pollutants (POPs).

Because of concern that the hazards, particularly to sensitive groups such as children, can be serious and irreversible and can take a long time to appear, governments are tending to legislate to reduce exposure without waiting for specific proof of harm (the precautionary principle).

In the context of these concerns there is a serious lack of monitoring and information on the concentration and distribution of potentially harmful substances in air, water, stream sediment, soil and food and little information on associated exposure and effects on people and ecosystems. Moreover, current toxicity risk assessments are based mainly on single substances, although people and ecosystems are generally exposed to complex mixtures. There is also a general lack of understanding that PHSs can occur naturally.

High-resolution systematic digital geochemical maps have been shown to be of value for addressing such problems at the national to local scale. Many countries already possess these data-sets. Typically, a range of trace elements including potentially harmful elements, radioactive elements and essential trace elements have been determined (although few if any geochemical maps include information on the distribution of POPs). The resulting data, usually in digital form, enable complex environmental geochemical problems to be identified in the context of natural background levels of chemical substances, which can be highly variable.

Unfortunately, the geochemical data currently available have been obtained mainly in the absence of any international standards and there have been considerable differences in the methods used to collect and analyse samples from a wide variety of sample types. Hence it is difficult to integrate and compare the data to assess environmental geochemical problems, including those which are of significance to human health at the international to global scale. This is a particular problem in developing countries where geochemical mapping has normally been carried out for mineral exploration.

IUGS/IAGC Working Group on Global Geochemical Baselines

(Project web-site: http://www.bgs.ac.uk/bgs/w3/argg/iugs/iugssyno.htm)

To address these problems, a Working Group was established by the International Union of Geological Sciences (IUGS) and the International Association of Geochemists and Cosmochemists (IAGC), following the successful International Geological Correlation Programme (IGCP) 259 and 360 projects led by Dr A. Darnley of the Geological Survey of Canada. The final report of IGCP 259 presents the issues which are important for such an undertaking and recommends the establishment of a Global Reference Network (GRN) consisting of a 5000 point geochemical sampling grid around the globe.

The aims of the project are to prepare a standardised global geochemical baseline, to document environmental problems and to provide a means of monitoring future changes in surface geochemistry. More than one hundred countries are participating in the project. Regional centres act as foci for co-operation and may be aid agencies, international organisations or collaborations of national or international bodies. In Europe, activities are co-ordinated by the Forum of European Geological Surveys (FOREGS). Detailed sampling, analytical and data interpretation methods to improve and standardise data quality have been agreed and published. The methods and resulting data are being disseminated to all participating countries through the project web-site as they become available.

These data can be used with other spatially related data-sets to identify potential hazards from harmful chemicals in surface and groundwater, soils, sensitive ecosystems and human populations. Such information can be used to refine, develop and validate models for the interaction of man and the environment at the local-global scale. Also, the data and their analyses can be used to demonstrate the distribution and extent of environmental problems to decision-makers, stake holders and individuals in a readily understood and attractive format using geographical information systems (GIS).

To this end, IUGS/IAGC Working Group is keen to develop links and contacts with other international initiatives and to combine these data-sets with information not normally associated with geochemistry.

On the basis of experiences with geochemistry and health and the Global Geochemical Baselines project, the following future research requirements are recommended.

Future Research Requirements

1. There is a need for greater international standardisation of data collection and reporting from all research disciplines so that links between environment and health can be assessed at the global scale. This process has been initiated in geochemistry via the IUGS/IAGC Global Geochemical Baselines Project.

2. There are many international monitoring projects organised by different research disciplines: ecosystem projects, air quality projects, soil monitoring projects etc. Currently there are no links between these different international programmes and it is difficult to compare the data. Methods to integrate monitoring networks should be investigated and there should be better communication and collaboration between all these international initiatives.

3. In order to study spatial links between environment and health, there is a need for greater georeferencing of data. This is particularly important for human health data, which is presently often reported as regional or district information. This makes the assessment of links between environmental factors and health difficult.

4. There is a need for more information on the sources, distribution and pathways of potentially harmful substances in the environment.

5. There is a need for more research into the health effects of potentially harmful substances in terms of exposure, mixtures of different substances, and dose-response relationships. Further toxicological studies are required to assess the controls on the health effects of environmental hazards in different populations. This will determine whether or not current accepted toxicological thresholds such as those adopted by the US-EPA and WHO can be applied globally.