Neil Breward and **Chris Johnson** explain how mapping the distribution of elements in surface waters and soils can help identify the risks, not only from toxins, but also from deficiencies in essential trace elements.

Living with the elements

Our universe is a cocktail of more than a hundred chemical elements, although only about ninety occur naturally on Earth. Everything within and about us has at least one element as a building block. Most elements (either individually or in the form of chemical compounds) are generally harmless, many — perhaps about thirty — are essential to life, while some can be poisonous. We take for granted essential elements for life such as the oxygen in the air we breathe, the combination of hydrogen and oxygen to give the water we all need, or the components of our bodies such as the calcium for our bones. We are aware of everyday elements we use in artefacts such as the metals; iron, copper, and silver. We are also aware that elements like lead and arsenic can be toxic, and that 'trace elements' in our diet such as zinc, selenium, and iodine, are important in keeping us healthy.

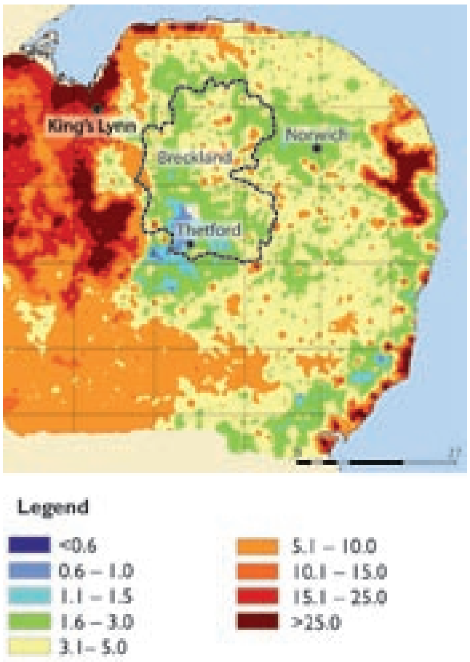
We interact with a relatively thin zone at the Earth's surface (the biosphere) that is only several metres deep, and the chemical composition of this zone is very dependent on geological, geomorphological, and climatic processes. However, particularly in the urban environment, anthropogenic (human) activity has had a significant impact, upsetting the chemical balance to create a contaminated and potentially unsafe environment. And this is especially true in towns and cities with a long history of heavy industry. For example, urban areas generally have higher levels of metals such as lead and tin in soils, than rural areas on similar bedrocks.

The Geochemical Baseline Survey of the Environment (G-BASE) project is defining a geochemical baseline for the UK land area by collecting and analysing drainage sediments, soils and stream waters for nearly 50 elements at a sampling density of about one site every two square kilometres. This provides the basic background data that can be used to model and interpret the behaviour of elements in the biosphere, allowing changes to the environment, both natural and man-made, to be monitored and their impact assessed. In contaminated urban areas, understanding both the baseline element levels and the extent of the contamination provides important information for any pollution clean-up procedures which may be required. Conversely, where high levels of an element have a natural source and are geochemically immobile (and therefore not an environmental or health risk), the cost of unnecessary and potentially hazardous clean-up work can be avoided.

Understanding the baseline levels of elements is essential in any study of the relationships of environment and health where the system comprises three key components:

Source — Pathway — Target

The ultimate source for any potentially toxic element is usually earth materials such as soil, rock and water. The pathway may involve transfer from soil to plants which are then eaten by animals. The 'target' then becomes the cells of the organism being studied, where any toxic effects occur. Although the pathway may be a combination of quite complex



Map of the survey area showing the Breckland region. Iodine concentrations in mg/kg in the topsoil of East Anglia, as revealed in the G-BASE.

geochemical and biochemical processes, the source is often the determining factor in whether toxic effects are produced. Other important controls include the 'speciation' or chemical form of the element, the acidity of the soil or water, and the interactions with other elements present.

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However, low levels of elements which are essential to life can also have detrimental health impacts, notably in agriculture where both arable crops and grazing stock animals may be prone to deficiency diseases. The geochemical maps produced by the G-BASE project are also valuable for showing such areas of vulnerability to potential trace element deficiency. Recent advances in the range of elements determined by G-BASE have enabled us to produce maps for selenium, bromine, and iodine, all biologically important trace elements with health implications. These are in addition to the trace metals copper and molybdenum, already surveyed by G-BASE, which are known to have associated deficiency diseases.

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The G-BASE project coverage has now extended into eastern, and south-eastern England. Our latest complete dataset is for East Anglia. Example maps are shown here for selenium, bromine and iodine in topsoils for this region, and show a strong affinity with the bedrock and Quaternary geology in most places. Low levels of these three elements are present over the free-draining sandy soils of the Brecklands north of Thetford, which contrast strongly with high values over the peaty alluvium-based soils of the Fens, the Norfolk Broads, and the Suffolk coast. The areas of peat on the south-east margin of the Fens around The Wash are especially enriched in all three elements, although iodine is more enriched in the marine alluvium of the Fens and coastal marshlands than bromine, and selenium levels are relatively low in these areas.

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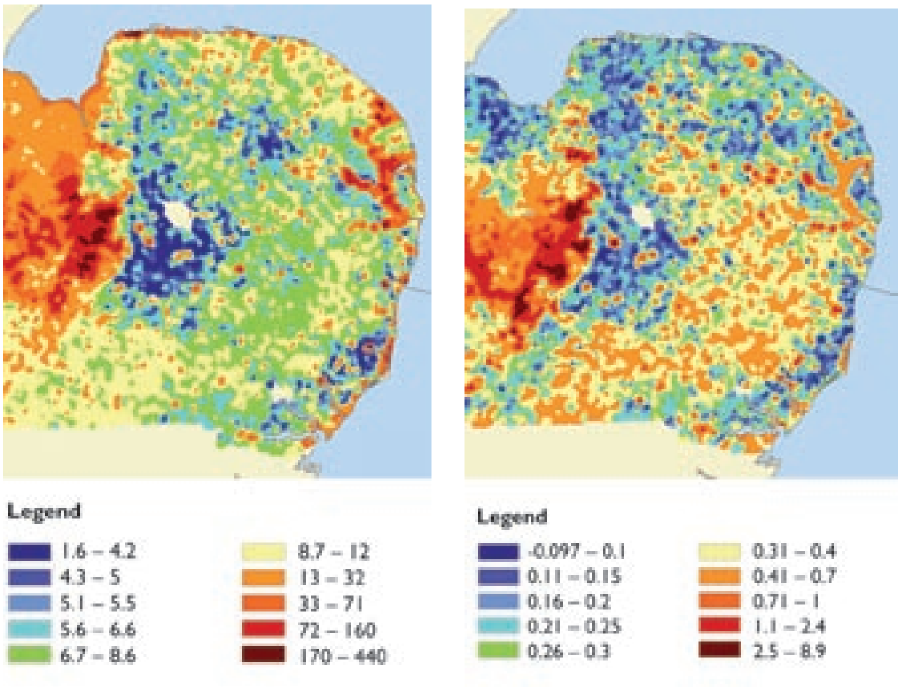
The Brecklands are clearly one area where deficiency diseases may be more likely to occur, while the peatlands appear to have an abundance of these elements. However, the variation in the bioavailability of the elements must be taken into account: perhaps the very strong bonding of bromine, iodine, and selenium to peat may actually induce deficiency problems? Cross-checking the soil data with other G-BASE datasets for stream water chemistry and acidity, for example, allows us to more readily assess the likelihood of this and similar problems arising.



Bromine (above left) and selenium (above right) concentrations mg/kg in the topsoil of East Anglia, as revealed in the G-BASE survey.

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