

THE SCIENCE OF THE TOTAL ENVIRONMENT

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From the time the earth was recognized as a sphere, scientists have spent much effort trying to reduce that sphere into various divisions that were easier to investigate. This led to the concept of "spheres" which was classified as the atmosphere (the gaseous part), the lithosphere (the solid part), the hydrosphere (the aqueous part) and the biosphere (the living part). Even though such a division may help in the easier study of the diverse earth processes, it will soon be essential conceptually, to integrate the knowledge that has been obtained about each of these components over the centuries to understand better how the total Earth System functions. There is a very close interaction between each of the "spheres" mentioned above, and the concept of the "geochemical cycle" which is extremely useful in the study of many of the earth's processes.

Geochemistry and Health

The growth, health, fertility and well-being of man and animals are known to be influenced by the amounts and proportions of the various trace elements to which they are exposed from soil, vegetation, water and the atmosphere. As such, the geochemistry of certain elements in a particular area govern to a large extent the general health of the people living in that particular area. Environmental geochemistry essentially deals with the geographical distribution of elements and forms the basis for a variety of interdisciplinary studies involving human and animal health, agriculture and nutrition, soil fertility, pollution and mineral exploration. The study of the abundance and distribution of some trace elements and the resulting biological manifestations involves geochemists, public health workers, soil scientists, ecologists and nutritionists.

Problems of trace element deficiency or excess affecting health and production of agricultural crops and livestock have been reported, and many of the occurrences can be related to the geology of the area or region affected. For example, areas underlain by acid igneous rocks such as granite or arenaceous sedimentary rocks generally contain lower levels of essential trace elements - particularly the first low transition elements - than areas underlain by ultrabasic and igneous rocks or shales. These, however, may sometimes contain sufficient concentration of a potentially toxic element that could be hazardous.

Well established relationships with the geochemical environment include iodine deficiency with goitre, fluoride deficiency with dental caries and fluoride excess with fluorosis. There are other controversial correlations with no proven causal relationship such as water hardness and cardiovascular diseases, lead and multiple sclerosis, cadmium and hypertension and arteriosclerosis, and a range of trace elements with cancer. Cancer in particular has been the subject of intensive study, and the overwhelming number of causative factors which have been isolated are in one way or another environmental. It has been shown that in industrial societies, environmental agents (air, water, working place, life style) have been responsible for 30-40 percent of human cancers and much research into the causes of cancer is now based on the hypothesis that all cancers are environmentally caused until the contrary is proved.

Table 1 shows the concentration of essential plant nutrients in natural materials. It is apparent that the presence or absence of nutrients depends to a very great extent on the geochemistry of the soil and underlying rocks.

Table 1 The concentration of essential plant nutrients in natural materials (ppm).

| Element | Rocks | | | | Soil (ppm) | Fresh Water (ppm) | Nutrient Solution (ppm) | Plant matter (Oven dry) | | Relative no. of atoms with respect to molybdenum (plant) |
|----------------|---------|---------|-----------|-----------|---------------|-------------------------|-------------------------------|----------------------------|-------------------|--|
| | Igneous | Shale | Sandstone | Limestone | | | | All plants (ppm) | Conifers (ppm) | |
| Micronutrients | | | | | | | | | | |
| Molybdenum | 1.5 | 2.6 | 0.2 | 0.4 | 2 | 0.00035 | 0.05 | 0.1 | 1 | 1 |
| Copper | 55 | 45 | 5 | 4 | 20 | 0.01 | 0.064 | 6 | 4 | 100 |
| Zinc | 70 | 95 | 16 | 20 | 50 | 0.01 | 0.065 | 20 | 30 | 300 |
| Manganese | 950 | 850 | 50 | 1,100 | 850 | 0.012 | 0.55 | 50 | 200 | 1,000 |
| Iron | 56,300 | 47,200 | 9,800 | 3,800 | 38,000 | 0.67 | 5.6 | 100 | 200 | 2,000 |
| Boron | 10 | 100 | 35 | 20 | 10 | 0.13 | 0.50 | 20 | 20 | 2,000 |
| Macronutrients | | | | | | | | | | |
| Chlorine | 130 | 180 | 10 | 150 | 100 | 7.8 | 3.5 | 100 | 1,000 | 3,000 |
| Sulphur | 260 | 2,400 | 240 | 1,200 | 700 | 3.7 | 48 | 1,000 | 800 | 30,000 |
| Phosphorus | 1,050 | 700 | 170 | 400 | 650 | 0.00541 | 41 | 2,000 | 1,300 | 60,000 |
| Magnesium | 23,300 | 15,000 | 10,700 | 2,700 | 5,000 | 4.1 | 36 | 2,000 | 1,000 | 80,000 |
| Calcium | 41,500 | 22,100 | 39,100 | 302,000 | 13,700 | 15.0 | 134-300 | 5,000 | 2,500 | 125,000 |
| Potassium | 21,000 | 26,700 | 11,000 | 2,700 | 14,000 | 2.3 | 130-295 | 10,000 | 8,000 | 250,000 |
| Nitrogen | 20 | — | — | — | 1,000 | 0.23 | 140-284 | 15,000 | 15,000 | 1,000,000 |
| Oxygen | 464,000 | 483,000 | 492,000 | 497,000 | 490,000 | 889,000 | — | 450,000 | — | 30,000,000 |
| Carbon | 200 | 15,000 | 14,000 | 11,400 | 20,000 | 11,000 | — | 450,000 | — | 35,000,000 |
| Phosphorus | 1,400 | 5,600 | 1,800 | 860 | 15,000 | 111,000 | — | 60,000 | — | 60,000,000 |

(After Fortescue 1979)

Figure 1 illustrates the paths of biogenic migration of chemical elements in the biosphere and their biogenic cycles. The link between geochemical environment which includes the chemical elements of rock, soil, water, air, microorganisms, plants, forages, food products, diets, animals and man, and the organisms is worthy of note.

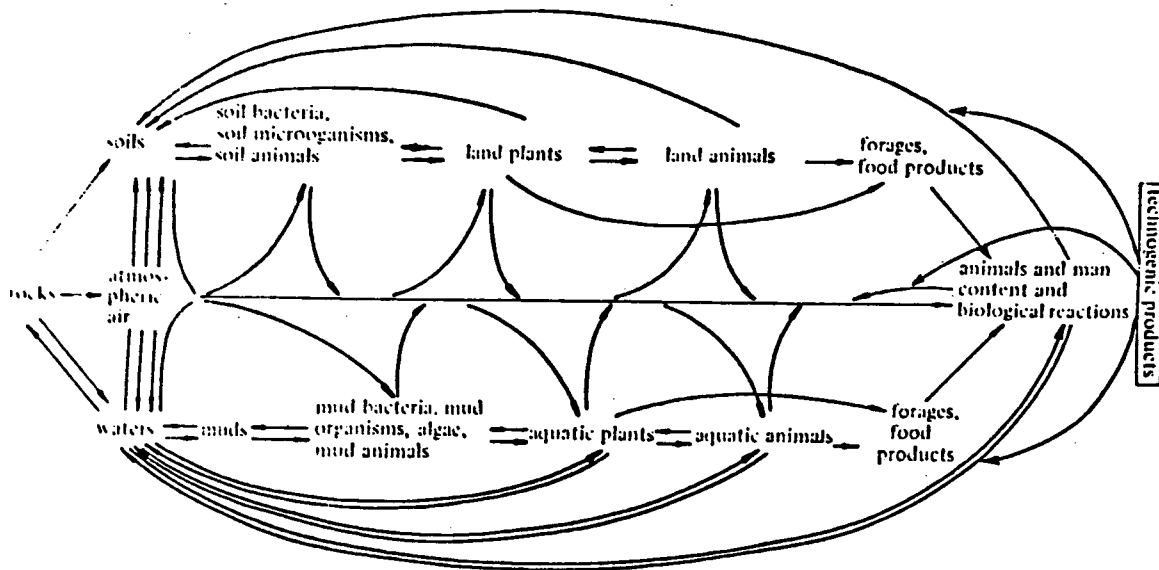


FIGURE 1. Biogeochemical food chain. Paths of biogenic migration of chemical elements in the biosphere and their biogenic cycles.

The biogenic cycles of chemical elements of subregions of the biosphere and biogeochemical provinces include a number of small cycles, and connect the separate links of the biogeochemical food chain with one another (Figure 2).

Examples are :

- (1) Soil - microorganisms
- (2) Soils - plant root systems
- (3) muds and waters of continental basins - aquatic and muddy organisms (bacteria, fungi, algae, flowering plants, animal organisms)
- (4) organisms - atmospheric air
- (5) pasture plants - forages, diets, animals
- (6) food products - diets - man

For a systematic study of the conditions of health and endemic diseases, one therefore needs to study the very close interactions between the various sub-cycles of the different 'spheres'.

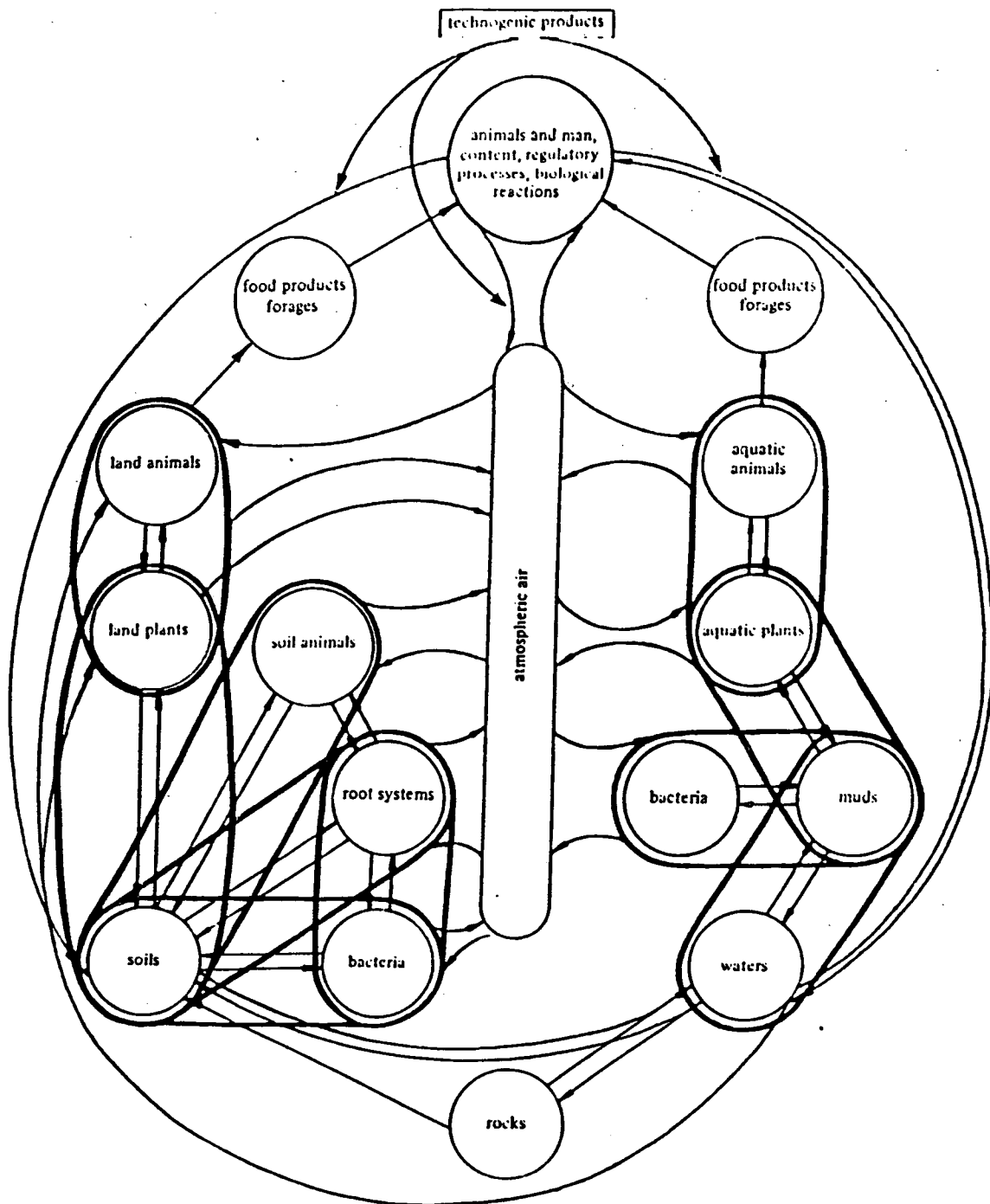


FIGURE 2. Biogenic cycles of chemical elements in the subregions of the biosphere and biogeochemical provinces.