TRACE ELEMENTS

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1. Introduction

Earth scientists generally view trace elements as those other than the eight abundant rock-forming elements found in the natural environment (i.e., O, Si, Al, Fe, Ca, Na, K, and Mg). From a geochemical viewpoint the term "trace element" is used for elements present in the earth crust in concentrations <1000 mg kg^{-1}. In biochemical and biomedical research, trace elements are considered to be those that are ordinarily present in plant or animal tissues in concentrations comprising <100 mg kg^{-1} of the organism dry matter. In food and nutrition science, a trace element may be defined as an element that is of common occurrence but whose concentration rarely exceeds 20 parts per million (ppm) in the foodstuffs as consumed. It should be noted that some of the nutritive trace elements (e.g., Mn and Zn) may often exceed this concentration (ADRIANO, 2001). – Therefore, the term trace element is rather loosely used in literature and has differing meanings in various scientific disciplines. Sometimes it is even defined as those elements used by organisms in small quantities but believed essential to their life cycle. However, it broadly encompasses elements including those with no known physiological functions. Trace elements refer generally to elements that occur in natural and perturbed environments in small amounts and that, when present in excessive bioavailable concentrations, are toxic to living organisms. Micronutrients are those elements required in biological processes. Heavy metals are elements having densities greater than 5.0 g cm^3 and denote metals and metalloids that are associated with pollution and toxicity but also include essential elements.

Trace elements to be considered are: arsenic (As), silver (Ag), boron (B), barium (Ba), beryllium (Be), cadmium (Cd), cobalt (Co), chromium (Cr), copper (Cu), fluorine (F), mercury (Hg), manganese (Mn), molybdenum (Mo), nickel (Ni), lead (Pb), antimony (Sb), selenium (Se), tin (Sn), thallium (Tl), vanadium (V), and zinc (Zn).

These metals and metalloid elements are ubiquitous. They occur naturally as ions, compounds and complexes (speciation) and - to an increasingly relevant degree – in the anthroposphere in a variety of forms. Many of them are extracted, purified and processed for industrial use and then released to the environment again (MERIAN, 1991), sometimes under incidental conditions (UNEP Survey of Tailings Dam Failures, 1966). Metals are used in various ways, as raw material for numerous industrial products or as catalysts in chemical processes. Some trace elements are constituents of pesticides or fertilizers. Appreciable amounts of them are emitted by the combustion of fossil fuels or in high-temperature processes. Principally, all trace elements may act as contaminants in gaseous, liquid, or solid wastes and may be distributed over large areas in connection with industrial, agricultural, or hygienic activities. As a result of global cycles and regional redistribution and conversion, all soils can be exposed to them locally in elevated concentrations through deposition (BLUM 1998).

Certain elements are, besides negative effects in high doses, essential for organisms in small amounts. Interactions with other substances in complex dynamic systems also have to be considered. The problem of soil system complexity has a lot of different aspects ranging from relatively simple abiotic components and reactions to very complex combinations of hierarchically organized bio-abiotic components and complex interactions among the macro-, mezo- and microbiota, gases, solutions and solid components (HUANG et. al. 2002; MERIAN 1991).

Current universal trace element research is being spurred by the need to increase food, fiber, and energy production; determine trace metal requirements and tolerances by organisms, including relationships to animal and human health and diseases; evaluate bioavailability of trace metals to organisms as influenced by biogeochemical processes and factors; evaluate the potential bioaccumulation, biomagnification, and biotoxicity of trace metals; understand trace metal cycling in nature, including their biogeochemistry; elucidate the importance of trace metals in environmental health, including urban and indoor environments (ADRIANO 2001).

The trace elements that have been studied most extensively in soils are those that are essential for the nutrition of higher plants (MARSCHNER 1995): B, Cl, Cu, Fe, Mn, Mo, Ni, and Zn, see table 1. Similarly, those extensively studied in plants and feedstuff because of their essentiality for animal nutrition are As, Cu, Co, Fe, Mn, Mo, Zn, Cr, F, Ni, Se, Sn, and V (MERIAN 1991), see table 1.

2. Sources and occurrence of Trace Elements in Soils

The total amount of trace elements in soil is derived in the first place from weathering of rock minerals, but may be increased substantially by man's industrial and agricultural activities (KABATA-PENDIAS 2000). There are generally higher quantities of trace elements in igneous than in sedimentary rocks. Igneous and metamorphic rocks are the most common source of trace elements in soil. They account for 95 % of the earth's crust with sedimentary rocks making up the remaining 5 %. Of the sedimentary rocks 80 % are shales, 15 % sandstones and 5 % limestones. Sedimentary rocks are the most important soil parent material since they overlie most igneous formations, to account for 75 % of the outcrops at the earth's surface (WEDEPOHL 1991). Typical element concentrates in soils are shown in Table 1.

Element	Soil	Plant
Antimony	0.1 – 2.0	0.01 – 0.1
Arsenic	1.0 - 10	0.1 – 0.5
Barium	100 - 1000	10 - 100
Beryllium	0.1 - 10	0.01 – 0.1
Boron	2.0 - 100	3.0 - 90
Cadmium	0.05 – 1.0	0.05 – 0.5
Chromium	10 - 50	0.1 – 0.5
Cobalt	1.0 - 10	0.02 – 0.5
Copper	10 - 40	3.0 - 12
Fluorine	100 - 500	1.0 - 10
Iron	10000 – 50000	50 - 200
Lead	10 – 30	0.1 – 0.5
Manganese	300 - 1000	20 - 400
Mercury	0.05 – 0.5	0.005 – 0.05
Molybdenum	0.5 – 2.0	0.1 – 4.0
Nickel	10 - 50	0.2 – 2.0
Selenium	0.1 – 2.0	0.01 – 0.5
Thallium	0.02 – 0.5	0.005 – 0.05
Tin	0.1 - 10	0.1 – 1.0
Vanadium	30 - 150	0.2 – 1.0
Zinc	20 - 200	20 - 100

Table 1: Typical trace element contents in soils and vegetative aboveground plant organs in $mg\ kg^{-1}$. Data are given for the range that can be observed frequently; according to ADRIANO (2001), KABATA-PENDIAS (2000), and own analyses.

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