TRACE ELEMENTS AS CONTAMINANTS AND NUTRIENTS

TRACE ELEMENTS AS CONTAMINANTS AND NUTRIENTS

Consequences in Ecosystems and Human Health

Edited by

M. N. V. Prasad

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FOREWORD

From the very beginning, metals such as gold, silver, copper, and iron have played a major role in the development and history of human societies and civilizations. Metals are dispersed on and in the Earth's crust, and methods for obtaining them from natural deposits have evolved over time. The distribution of metals is not uniform, and localized deposits serve as ores for metals, usually found as compounds, combined with other minerals and inorganic anions. If the concentration of the desired metal is high enough in the deposit for an economical extraction, then the ore can be exploited for a short or long period, depending on the state of the art and technology of mining. Most metals have to be purified or refined and then reduced to the metallic state before use. For example, the production of steel from iron requires the elimination of impurities present in the rocks, followed by the addition of other metals to obtain steel with the desired properties, such as hardness and resistance to corrosion. The science and technology of metals is precisely called "metallurgy." Our post-modern society is still based on the use of metals, and some major applications are briefly mentioned below:

- Potassium chloride is used as a fertilizer, and potash (K_2CO_3) is used in making soft soaps, pottery, and glass. Potassium hydroxide is an electrolyte in alkaline batteries, and NaOH is the most important base for industry. Soda ash (Na_2CO_3) is mainly used to make glass, but is also required to prepare chemicals, paper, and detergents. $NaHCO_3$ is an additive to control water pH in swimming pools, as well as to provide the fizz and neutralize excess stomach acid in analgesic drugs.
- Magnesium and calcium are good heat and electricity conductors. Alloyed with aluminum, Mg produces a strong structural metal. Another use of Mg is in fireworks. Epsom salt ($MgSO_4$) is useful in the tanning of leather and to treat fabrics. Milk of magnesia ($Mg(OH)_2$) has antacid and laxative properties. $CaCI_2$ is used to remove moisture from very humid places; CaO is a major ingredient in Portland cement, and partially dehydrated $CaSO_4$ (gypsum) produces plaster of Paris.
- Chromium is resistant to corrosion and is excellent as a protective coating over brass, bronze, and steel. Chromium is also needed to produce alloys such as stainless steel or nichrome; the latter is often used as the wire heating element in various devices such as toasters. Compounds of Cr have many practical

applications, such as for pigments production and leather tanning. The main use of manganese is as an additive to steel and in the preparation of different alloys.

- Iron and its alloys have such physical properties that they have been put to more uses than any other metal. Nickel is one of our most useful metals; in its pure state, it resists corrosion, and it is thus frequently layered on iron and steel as a protective coating by electrolysis. When alloyed with iron or with copper, Ni makes the metal more ductile and resistant to corrosion and to impact.
- Copper has a very high electrical and thermal conductivity and is thus used in electrical wiring. It is also resistant to corrosion and thus appropriate to carry hot and cold water in buildings. Cu does oxidize slowly in air; and when CO_2 is also present, its surface becomes coated with a green film.
- Zinc provides a protective coating on steel, in a process called galvanizing. It is also used in various alloys, like brass (Cu and Zn) and bronze (Cu, Sn, and Zn). Zinc is important in the manufacture of zinc carbon dry cells and other batteries. Zinc oxide is used in sunscreens and to make quick-setting dental cements. Zinc sulfide is suitable to prepare phosphors that glow when submitted to UV light or high-energy electrons of cathode rays, like the inner surface of TV picture tubes and the displays of computer monitors. Cadmium is useful as a protective coating on other metals and for making Ni Cd batteries.
- In the past, lead was used for pipes and as an additive to gasoline. Nowadays, Wood s metal consists of an alloy of Bi, Pb, Sn, and Cd, melting at 70°C only, used to seal the heads of overhead sprinkler systems: A fire triggers the system automatically by melting the alloy. Different lead oxides are also needed in making pottery glazes and fine lead crystal; in corrosion-inhibiting coatings applied to structural steel; and as the cathode in lead storage batteries.

However, metals not only play an essential role in our daily life, but also are released into the environment in an uncontrolled way and become contaminants, or even pollutants. A contaminant is present where it would not normally occur, or at concentrations above natural background, whereas a pollutant is a contaminant that cause adverse biological effects to ecosystems and/or human health. In such a context, green plants play a key role in the availability and mobility of metals. Plants can remove metals from contaminated soils and water for cleanup purposes. Several plant species, hyperaccumulating elements like nickel, gold, or thallium, can be used for phytomining. On the other hand, crops with a reduced capacity to accumulate toxic metals in edible parts should be valuable to improve food safety. In contrast, crop plants with an enhanced capacity to accumulate essential minerals in an easily assimilated form can help to feed the rapidly increasing world population and improve human health through balanced mineral nutrition. Because many metals hyperaccumulated by plants are also essential nutrients, food fortification and phytoremediation are thus two sides of the same coin. The different chapters of this book do address the dual role of trace elements as nutrients and contaminants and review the consequences for ecosystems and health.

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PREFACE

It is a general belief that the fruits and vegetables that our parents ate when they were growing up were more nutritious and enriched with essential mineral nutrients and were less contaminated with toxic trace elements than the ones that are being consumed by us currently. A study of the mineral content of fruits and vegetables grown in Great Britain between 1930 and 1980 has added weight to that belief with findings of such decreases in nutrient density. The study, conducted by scientists in Great Britain, found significantly lower levels of calcium, magnesium, copper, and sodium in vegetables, as well as significantly lower levels of magnesium, iron, copper and potassium in fruits. Research studies are showing that the reducing nutritional value and the problem of contamination associated with food quality is increasing at an alarming rate. The decline in quality of agricultural produce has corresponded to the period of increased industrialization of our farming systems, where emphasis has been on cash crop cultivation that demands high doses of agrochemicals—that is, fertilizers and pesticides.

Several of the trace elements are essential for human as well as animal health. However, nutritionally important trace elements are deficient in soils in many regions of the world and the health problems associated with an excess, deficiency, or uneven distribution of these essential trace elements in soils are now a major public health issue in many developing countries. Therefore, the development of "foods and animal feeds" fortified with essential nutrients is now one of the most attractive research fields globally. In order to achieve this, knowledge of the traditional forms of agriculture, along with conservation, greater use of native bio-geo-diversity, and genetic diversity analysis of the cultivable crops, is a must.

A number of trace elements serve as cofactors for various enzymes and in a variety of metabolic functions. Trace elements accumulated in medicinal plants have the healing power for numerous ailments and disorders. Trace elements are implicated in healing function and neurochemical transmission (Zn on synaptic transmission); Cr and Mn can be correlated with therapeutic properties against diabetic and cardiovascular diseases. Certain transition group elements regulate hepatic synthesis of cholesterol. Nutrinogenomics, pharmacogenomics, and metallomics are now emerging as new areas of research with challenging tasks ahead.

Soil, sediment, and urban dust, which originate primarily from the Earth's crust, is the most pervasive and important factor affecting human health and well-being. Trace element contamination is a major concern because of toxicity and the threat to human life and the environment. A variety of elements commonly found in the urban environment originate technogenically. In an urban environment, exposure of human beings to trace elements takes place from multiple sources, namely, water transported material from surrounding soils and slopes, dry and wet atmospheric deposition, biological inputs, road surface wear, road paint degradation, vehicle wear (tyres, body, brake lining, etc.), and vehicular fluid and particulate emissions. Lead and cadmium are the two elements that are frequently studied in street dust, but very little attention has been given to other trace elements such as Cr, Cu, Zn, and Ni, which are frequently encountered in the urban environment.

Street dusts often contain elevated concentrations of a range of toxic elements, and concerns have been expressed about the consequences for both environmental quality and human health, especially of young children because of their greater susceptibility to a given dose of toxin and the likelihood to ingest inadvertently significant quantities of dust. Sediment and dust transported and stored in the urban environment have the potential to provide considerable loadings of heavy metals to receiving water and water bodies, particularly with changing environmental conditions. On land, vegetables and fruits may be contaminated with surficial deposits of dusts. Environmental and health effects of trace metal contaminants in dust are dependent, at least initially, on the mobility and availability of the elements, and mobility and availability is a function of their chemical speciation and partitioning within or on dust matrices. The identification of the main binding sites and phase associations of trace metals in soils and sediments help in understanding geochemical processes and would be helpful to assess the potential for remobilization with changes in surrounding chemistry (especially pH and Eh). Sophisticated analytical and speciation techniques and synchrotron research are being applied to this field of research in developed nations.

This book covers both the benefits of trace elements and potential toxicity and impact of trace elements in the environment in the chosen topics by leaders of the world in this area.

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