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Effects of trace elements on the critical functioning of human health

R. Nagendra[1] and A. Nallapa Reddy[2]*
[1]Formerly at Department of Geology, Anna University Chennai-600025
[2]Formerly at RGL, ONGC, Chennai-600048
*Corresponding email: geonag@gamil.com

Introduction

Trace elements are defined as those that are present in <0.1% by weight in rocks, minerals, soils, sediments, and water. They include a variety of elements, such as vanadium, zinc, cobalt, copper, manganese, nickel, and chromium, among others. Even though they are regarded as minor components, studying their geochemical behaviour and distribution patterns can help us understand the genesis, evolution, and alteration of geological materials. The origins and history of rocks can be traced using trace elements, which act as geochemical fingerprints. The existence of different mineral phases, the kind of magma, and the degree of partial melting can all be determined by the quantities and ratios of particular trace elements. This knowledge can be used to classify rocks and determine the tectonic environment and processes that led to their formation. Trace elements are essential for mineral discovery. Geologists can discover possible mineral deposits, determine their size and grade, and direct exploration activities by analysing trace element signatures. Trace elements are frequently employed as geochemical proxies to recreate historical environmental conditions in order to understand Earth's history. Researchers are able to determine paleoclimatic patterns, oceanic conditions, volcanic activity, and changes in atmospheric composition by examining the trace element concentrations in sedimentary rocks.

This knowledge aids in the comprehension of long-term climate fluctuations and the effects of human activity on the ecosystem. Besides using trace elements to establish the age of rocks and minerals, radiometric dating techniques use specific trace elements like uranium, thorium, and potassium. The absolute ages of geological events, such as the formation of rocks and the timing of volcanic eruptions, can be determined by geologists by observing the decay of radioactive isotopes and their daughter products. Trace elements are crucial environmental quality indicators that can be used to evaluate how human activities affect ecosystems. They can serve as indicators of pollution sources, help locate contaminated areas, and assess the success of remediation activities based on their existence and concentrations in soils, sediments, and water bodies. Monitoring trace elements aids in the understanding of the ecological risks associated with mining, industrial activity, and urban growth, which promotes sustainable resource management and environmental protection.

Nature's trace element concentrations

Trace elements can be found in a variety of soils, aquatic bodies, and living things. Even though they are in trace amounts, these elements are essential for ecological processes, biogeochemical cycles, and ecosystem health. The concentrations, sources, distribution, and importance of trace elements in nature are significant. Trace elements are formed from geological formations and minerals. Weathering and volcanic activity play a role in the release of trace elements into the environment. The quantity and accessibility of trace elements are influenced by the types of rocks and mineral compositions. In addition, human activities such as mining, agriculture, industrial processes, and the combustion of fossil fuels can release trace elements into the environment. These human-made sources have a big impact on trace element concentrations in specific places, which might contaminate the ecosystem. Trace element distribution in soils is influenced by things including soil type, pH, organic matter content, and human activity. The availability and movement of trace elements might be improved by particular soil characteristics. The surface waters, groundwater, lakes, rivers, and seas all naturally contain trace elements. They can get into water sources through atmospheric deposition, soil and rock degradation, and anthropogenic inputs. Trace element concentrations in water are affected by a number of variables, including pH, temperature, salinity, and the presence of suspended particles. Trace elements are essential micronutrients for all living organisms. They are absorbed from the soil by plants, moved up the food chain, and accumulated by various creatures. The concentration of trace elements in an organism depends on its biological makeup, dietary preferences, and exposure to the environment.

Impacts and Significance

Trace elements are vital for biochemical reactions, enzyme activity, and metabolic processes in living things. They support the movement of nutrients, the exchange of energy, and the control of growth in ecosystems. Trace element concentrations must be sufficient for ecosystems, both terrestrial and aquatic, to be robust and

productive. Although trace elements are necessary for human health, their consumption can be harmful if it is excessive or insufficient (Fig. 1). A variety of health issues can be caused by trace element toxicities or deficiencies. Inadequate intake of iron or iodine, for instance, can result in anemia or thyroid diseases, whereas excessive exposure to heavy metals like lead or mercury can harm the nervous system. Due to increased anthropogenic activity, soils, water bodies, and ecosystems may become contaminated with high concentrations of trace elements. Agricultural practices, inappropriate waste disposal, and industrial emissions can all lead to contaminated environments. Both ecological integrity and the public's health are at risk from these elevated trace element concentrations. It is crucial to regularly check the amounts of trace elements in environmental matrices in order to gauge environmental quality and find contamination. In order to reduce the risks brought on by elevated trace element concentrations and restore environmental health with the aid of strategies including phytoremediation, soil improvements, and water purification methods.

Soil and human health

Soil composition is a key factor in defining the productivity and health of ecosystems. Minerals, organic matter, water, air, and living things all coexist in complicated ways in soil. Soil composition changes depending on the climate, parent material, geography, and time. The organic matter in the soil is made up of decomposed plant and animal matter, soil composition components, and their impact on human health. It develops soil structure, increases the soil's ability to retain water, and promotes good microbial activity. Organic matter encourages healthy plant development, which increases crop yields and strengthens ecosystem stability. The organic matter in the soil improves soil fertility by ensuring that vital nutrients are available for plant growth. It supports soil water retention, lowering the likelihood of drought stress and enhancing long-term plant output. Besides, it promotes soil biodiversity and healthy microbial populations, both of which are essential for nutrient cycling and disease prevention.

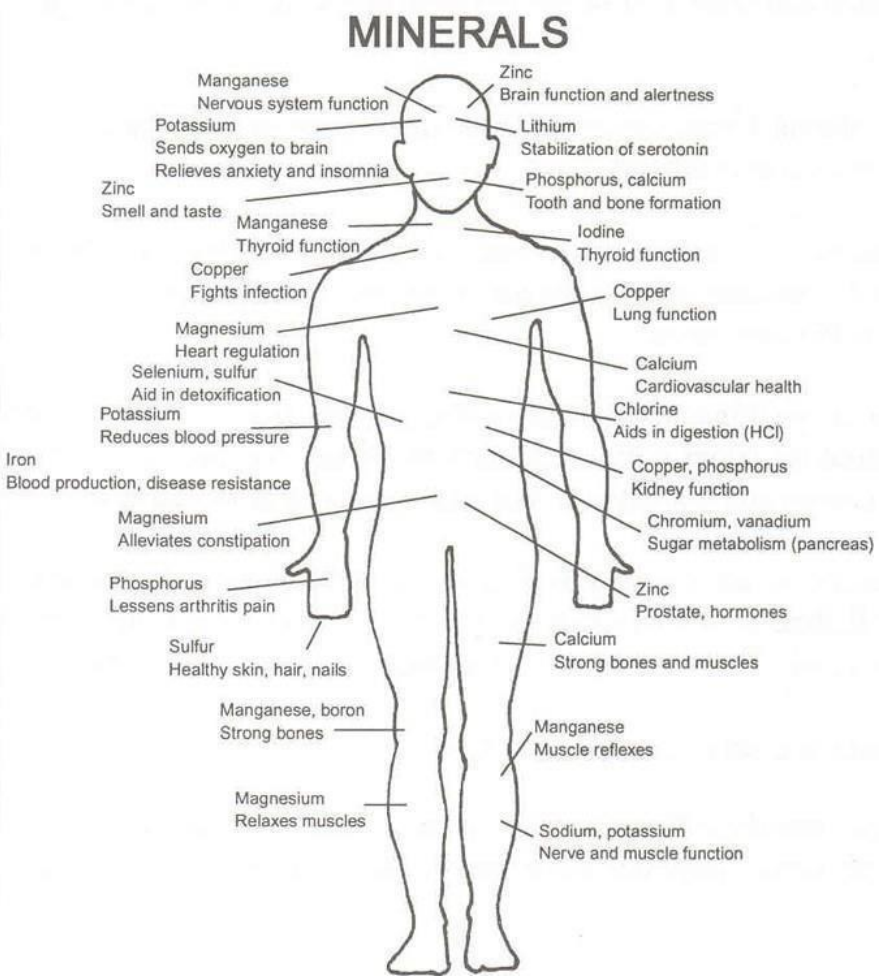

Fig. 1. Essential minerals for the human body (Source: https://blog.inlifehealthcare.com/7- essential-minerals-natural-food-sources/).

The availability of nutrients and microbial activity is influenced by the acidity or alkalinity of the soil, which is measured by pH. Certain plants require a precise pH range in order to grow. Alkaline soils (high pH) can alter nutrient intake, while acidic soils (low pH) may limit the availability of nutrients. Plants' ability to access and absorb vital nutrients depends on the pH of the soil. Crop toxicities or nutrient deficits can result from unbalanced pH levels. For crops to have the best nutrient content and sustain a balanced and nourishing diet for human health, proper soil pH control is essential. The relative amounts of sand, silt, and clay particles make up the soil texture. It has an impact on drainage, nutrient-holding capacity, and water infiltration. Different soil textures have unique properties and maintenance needs. Plants access to water is influenced by the texture of the soil. Clayey soils may have poor drainage and waterlogging. while sandy soils may endure drought stress due to their decreased water-holding capacity. By managing soil texture properly, such as by increasing organic matter content and soil structure, it is possible to increase the availability of water and nutrients to plants, which will increase crop productivity and nutritional value. Heavy metals, pesticides, and industrial pollutants can also be found in soil. Through direct exposure to or contamination of food crops, contaminated soils pose a threat to the environment and human health. The crops grown in contaminated soils may accumulate toxic chemicals that endanger human health if ingested. Long-term chronic diseases, skin disorders, and respiratory problems are a few of the negative health effects that can result from direct contact with or inhalation of soil toxins.

The effect of geological interactions on human health

Human health is significantly impacted by the interactions of rocks, soil, water, and air during geological processes. The existence of toxic compounds and the accessibility of vital nutrients are impacted by the composition and quality of these geological components.

Rocks: Radon can be released by several types of rocks, particularly granite and formations rich in uranium. Lung cancer risk can be raised by prolonged exposure to Radon. The soil and water nearby may be contaminated by rocks that contain heavy metals like arsenic, lead, and mercury. The effects of these metals on humans can include developmental delays, neurological disorders, and organ damage.

Soil: The geological makeup of soil can introduce toxins that have an impact on human health. For instance, heavy metals can be released into the soil during mining operations, increasing the possibility of contamination throughout the food chain. The availability of crucial nutrients for crops is determined by the composition of the soil. Food that is deficient in nutrients due to poor soil quality or mineral deficiency may result in malnutrition and related health issues.

Water: Groundwater is a crucial supply of drinking water for many people and can be affected by geological processes. If consumed in high proportions, contaminants from rocks and soil, such as arsenic, fluoride, and nitrates, can leak into groundwater and pose health hazards. The geological characteristics of an area influence the mineral content of water sources. While certain minerals can be beneficial to health, excessive intake of others, such as high levels of calcium or magnesium, may have adverse effects.

Air: Particulate matter can be released into the atmosphere by geological processes, including volcanic eruptions and dust storms. Inhaling these tiny particles can worsen pre-existing respiratory disorders and cause cardiovascular and respiratory complications.

Airborne toxins: A number of geological events, such as gas leaks or the release of volatile organic compounds from rocks and soil, can cause risky airborne toxins to exist. These poisons have the potential to harm the nervous system, induce cancer, or irritate the respiratory tract over time.

Mitigation and prevention: (a) It's important to regularly examine geological interactions and how they affect people's health. In order to detect potential hazards and implement preventative actions, governments, health organisations, and research institutions should collaborate to increase awareness, carry out surveys, and create monitoring programmes. (b) Proper land use planning is crucial, especially in places vulnerable to contamination or geological hazards. Health hazards can be reduced by putting legislation and standards for safe practices in land development, waste disposal, and mining into practice. (c) Using efficient water treatment techniques, such as filtration and disinfection, can help reduce toxins in water sources. Similar to the way

improving air quality can be attributed to reducing air pollution, managing industrial emissions, and supporting sustainable energy sources.

Macronutrients

Macronutrients are necessary minerals that the body needs in trace amounts for optimum health. These substances are essential for the production of hormones, the immunological response, and many other crucial processes.

Iron: It is an essential element for the transportation of oxygen and the creation of energy. Haemoglobin, the protein in charge of carrying oxygen in the blood, contains iron. Adenosine triphosphate, the body's main energy currency, is also produced with the help of iron. Anaemia, which causes weakness, weariness, and reduced cognitive function, can develop from low iron levels. When rapid growth and development occur throughout pregnancy and childhood, adequate iron consumption is essential.

Zinc: Zinc is vital for the proper operation of the immune system. Cell division, DNA synthesis, and wound healing are all impacted by it. Furthermore, zinc is necessary for healthy growth and development, especially during infancy and adolescence. Zinc deficiency can impair immunological function, hinder the healing of wounds, and restrict growth.

Iodine: It is crucial in the synthesis of thyroid hormones and brain development. The manufacture of thyroid hormones, which control metabolism and promote growth and development, depends on the trace element iodine. Inadequate iodine intake can cause iodine deficiency issues, such as goitre, an enlargement of the thyroid gland.

Selenium: As an antioxidant, selenium guards against the harm that free radicals can do to cells. The synthesis and activation of thyroid hormones depend on them, lowering the risk of developing some chronic diseases.

Copper: It has a role in a number of physiological processes, such as iron metabolism, connective tissue development, and energy production. It is a co-factor for various enzymes involved in the production of collagen, the defence against free radicals, and the creation of neurotransmitters. Anaemia, deformities of the bones, and poor neurological function can result from copper deficiency. A varied diet is essential for balancing copper intake for optimum health.

Micronutrients

Micronutrients are necessary for a variety of biological activities in both plants and animals. Although they are found in trace amounts in plants, grains, and herbs, they are vital to human health. The food grains, including oats, corn, wheat, and rice, contain trace components that add to their nutritional worth. Whole grains, in particular, contain trace elements that can provide a significant amount of dietary iron. As a vital trace mineral, food grains such as wheat and rice contain different quantities of zinc. Although the amount depends on the soil conditions in which they are cultivated, grains like wheat and rice can help with selenium consumption. Due to their trace element presence, herbs add extra nutritional value. Typical illustrations include trace minerals like iron, manganese, and zinc found in basil. Thyme is an excellent provider of manganese and iron. Consuming cinnamon regularly can help you get enough manganese and copper in your diet.

Plants and vegetables provide a wide variety of trace element sources and offer a range of micronutrients to support general health. Iron and manganese-rich vegetables, including spinach, are popular choices. Broccoli and cauliflower are abundant sources of manganese and selenium. Lentils and chickpeas are rich in iron, zinc, and copper. In order to ensure an appropriate intake of trace elements without reaching dangerous levels, maintain a balanced and varied diet that includes a variety of food grains, herbs, and plants.

Macro- and micronutrients for human health

The maintenance of human health depends on macro- and micronutrients, which are necessary for the human body to function effectively. While micronutrients are needed in lesser amounts, macronutrients must be consumed in greater proportions. The body requires more macronutrients to support and generate energy for a variety of physical processes. The body's main source of energy is carbohydrate-based. They are made up of fibre, starches, and sugars. Glucose, a product of the breakdown of carbohydrates, is used by cells as an energy

source. A daily diet of 45–65% of total calories should come from carbs. Whole grains, fruits, vegetables, legumes, and whole grains are all excellent nutritional sources of carbs.

Proteins are necessary for the development, maintenance, and repair of bodily tissues. They are made up of amino acids, which serve as the basis for proteins. Proteins are essential for the synthesis of enzymes, immune system activity, hormones, and antibodies. Depending on age, gender, and amount of exercise, the daily recommended intake of protein ranges from 10 to 35% of the total calories consumed. In addition to serving as an essential energy source, fats protect body organs, support the absorption of fat-soluble vitamins, and are necessary for the formation of hormones. Monounsaturated and polyunsaturated fats, in particular, are thought to be better alternatives to saturated fats and should be consumed in moderation.

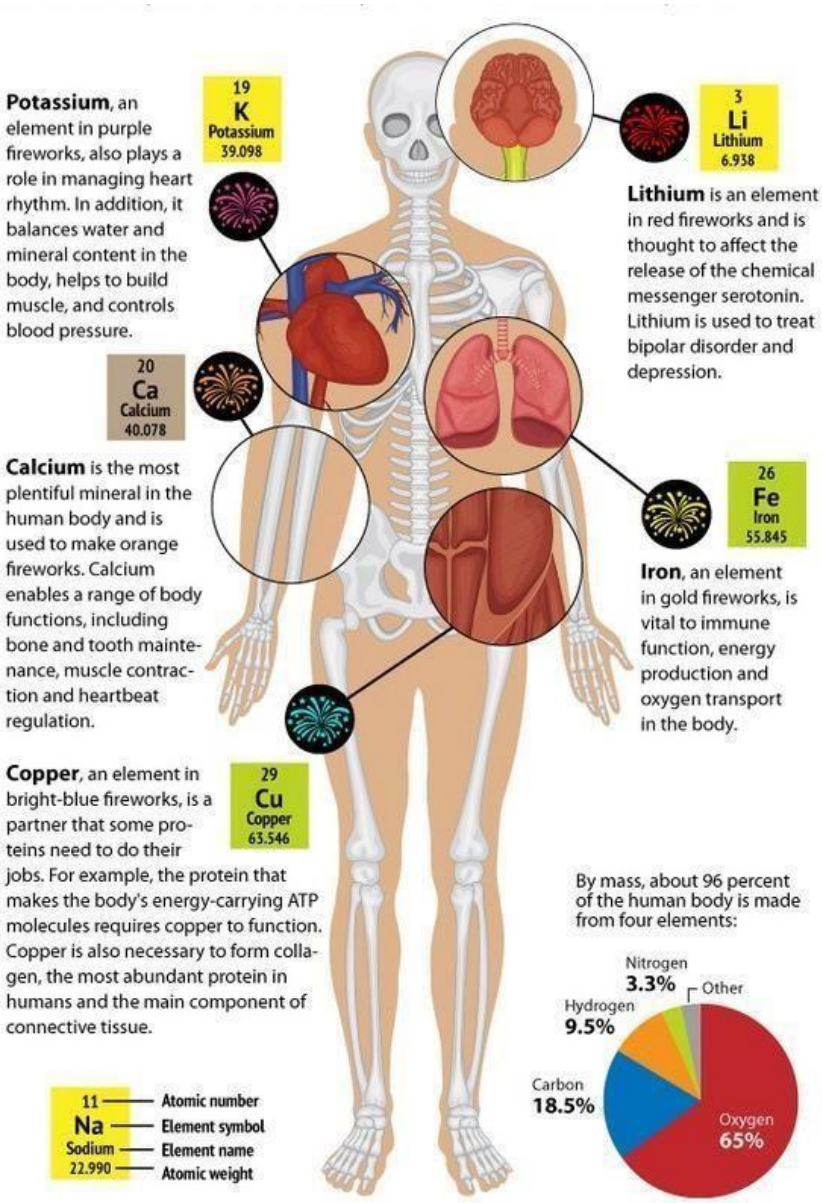

Fig. 2. Elements in the human body (Source: Live Science- https://www.livescience.com).

Organic substances called vitamins are necessary for many physiological processes. They function as coenzymes, aiding enzymes in carrying out crucial bodily chemical reactions. Water-soluble vitamins, such as vitamin C and the B vitamins, and fat-soluble vitamins, like vitamins A, D, E, and K. Each vitamin has a unique role and a set of food sources.

Minerals are inorganic substances that are essential for many body processes, including bone development, nerve conduction, and enzyme functioning. The major minerals calcium, magnesium, sodium, potassium, and phosphorus are needed in greater proportions. Iron, zinc, copper, iodine, selenium, and other trace minerals are needed at trace levels (Fig. 2).

Table 1. Functions of macro- and micronutrients (Source: G. Cortecci, F.R. Siegel and O. Selinus e A.Frank. (http://www.bibalex.org/supercourse/supercourseppt/16011- 17001/16081.ppt).

Nutrients	Functions
Fe	Essential compounds of hemoglobin and enzymatic complexes are required for energy generation and the immunological system.
Mn	Promotion of growth and development; cellular function; in bones and cartilages; takes part in metabolic reactions. Excess leads to surplus blood. May cause neurological diseases if inhaled into the lungs.
Se	Prevention of vascular and other diseases; neutralization of cell oxidation and aging of free radicals. Excess makes nails and hair brittle
Zn	It occurs in all tissues, mostly bones, muscles, and skin; active in the immunological system; regulates body growth; and protects the liver. Deficiency reduces body growth.
Co	Active in vitamin B12 and in chemical reactions. Deficiency causes anemia. Excess causes heart failure.
Cr	Needed for the metabolism of sugar. Deficiency may cause diabetes, intolerance to glycose, etc. An excess may result in renal failure. Excess Cr6 is carcinogenic.
Cu	Component of oxidizing enzymes during the metabolism of energy sources; active in the synthesis of hemoglobin in keratinization and in skin and hair pigments. Deficiency Leads to osteoporosis and a low number of white blood cells.
F	Gives strength to teeth and bones, temperature control, body growth, reproduction, etc. Deficiency causes abnormal growth of the thyroid.
I	Required by thyroidal hormones, temperature control, body growth, reproduction, etc. Deficiency causes abnormal growth of the thyroid.
Ca	Strengthening of bones and teeth; muscular activity; blood coagulation; cellular permeability. Excess may originate from liver and bladder stones and renal insufficiency.
Cl	Maintenance of blood pressure; vital as an acid constituent during digestion.
K	Maintenance of corporeal fluids; muscular contractions and nervous impulses.
Mg	In bones, together with Ca; activation of muscular contractions; body temperature control; and component of several enzymes.
Na	Active in hydrosaline equilibrium; transmission of nervous impulses; and transport of metabolites.
P	Bone constitutes an apatite; and participates in most body chemical reactions. Excess makes hair and bones brittle.

Conclusions

- Trace elements are essential for preserving human health. These necessary minerals are engaged in critical physiological processes and biochemical reactions in the human body, while only being needed in trace amounts. Each trace element iron and zinc to copper, selenium, iodine, and many others- serves a particular purpose that is important for metabolism, growth, and general health maintenance.
- Trace element deficiencies can affect many different biological processes and cause a variety of health problems. The effects of trace element shortages can include anemia, thyroid issues, a reduced immune system, poor growth, and slower wound healing.
- Consuming too much of some trace elements might be harmful. For optimum health, it's crucial to maintain a balanced, varied diet that includes food sources rich in trace elements.
- Ensure an appropriate intake of these vital minerals by including seafood, lean meats, nuts, seeds, whole grains, fruits, and vegetables in your diet. Dietary supplements could be required in some situations to address particular shortfalls or increasing needs.
- Understanding and addressing people's dietary needs is crucial because of the vital role that trace elements play in human health, growth, development, metabolism, and general well-being.

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