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THE CHEMICAL ROLE OF BIOGENIC ELEMENTS IN THE HUMAN BODY AND PATHOLOGICAL CONDITIONS ASSOCIATED WITH THEIR DEFICIENCY

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ABSTRACT

This article analyzes the chemical and biological significance of biogenic elements in the human body and explains how their deficiency leads to clinically important pathological conditions. The study was structured around both macroelements and microelements, with special attention to calcium, phosphorus, magnesium, sodium, potassium, iron, iodine, zinc, and selenium. Their participation in enzyme systems, membrane potentials, bone mineralization, oxygen transport, endocrine regulation, antioxidant defense, and cellular signaling was examined from a bioinorganic and clinical perspective. The purpose of the article was to present the physiological roles of these elements within a single conceptual framework and to connect their chemical forms and biological functions with the most common deficiency syndromes observed in medical practice. The analysis showed that biogenic elements are not passive nutritional components but active chemical determinants of metabolism, gene expression, redox balance, and tissue homeostasis. Their deficiency does not usually manifest as an isolated biochemical event; rather, it develops into a multisystem pathological response involving structural, functional, and regulatory disruption. The article also emphasizes that accurate diagnosis requires attention to early biochemical markers before overt clinical disease appears.

Keywords: Biogenic elements, macroelements, microelements, calcium, phosphorus, magnesium, iron, iodine, zinc, selenium, hematopoiesis, hypothyroidism, anemia, hypocalcemia, hypomagnesemia, bioavailability, metabolism

INTRODUCTION

Biogenic elements are chemical elements that form part of living matter and are indispensable for the continuity of vital processes. Some of them are organogenic elements that constitute the fundamental framework of biomolecules, while others are macroelements and microelements that participate in ionic regulation, metalloprotein function, hormone synthesis, membrane stability, and structural organization. When the human body is approached not merely as a collection of organic substances but as a high-order chemically regulated system, the importance of biogenic elements becomes much more evident. Ionic gradients between extracellular and intracellular compartments, enzyme activation, oxidation-reduction reactions, protein synthesis, skeletal mineralization, oxygen transport, and endocrine signaling all depend on them.

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From a physiological standpoint, biogenic elements may be divided into several conditional groups. Carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur form the main architecture of organic molecules. Sodium, potassium, calcium, magnesium, and chloride serve as principal macroelements responsible for electrolyte balance, osmolarity, excitability, and structural support. Iron, zinc, iodine, copper, selenium, manganese, and molybdenum are trace elements, yet their low concentration does not imply low importance. On the contrary, they are crucial for metalloenzymes, transcriptional control, hormone biosynthesis, electron transfer, and antioxidant protection. Because of this, trace element deficiency is often detected late, even though its consequences may be severe.

Deficiency of biogenic elements remains a major global health challenge. Iron deficiency is the most common cause of nutritional anemia worldwide. Iodine deficiency disrupts thyroid hormone synthesis and may lead to goiter, hypothyroidism, and impaired neurodevelopment in the fetus and child. Inadequate calcium and vitamin D intake contributes to rickets, osteomalacia, and reduced bone mineral density. Magnesium deficiency increases neuromuscular excitability and can provoke tremor, muscle spasm, and cardiac rhythm disturbances. Deficiency of zinc and selenium weakens immune competence, impairs tissue regeneration, and compromises antioxidant defense. Therefore, the medical significance of biogenic elements extends far beyond nutrition and enters the domain of pathogenesis, prevention, and long-term tissue function.

A persistent problem in clinical practice is that mineral deficiency is often evaluated only as a secondary feature of another syndrome rather than as a primary biochemical disorder. Anemia may be treated as a reduction in hemoglobin concentration without full assessment of iron absorption, ferritin reserves, transferrin saturation, hepcidin regulation, or chronic inflammation. Likewise, goiter is sometimes described only as thyroid enlargement, whereas the underlying mechanism includes reduced synthesis of triiodothyronine and thyroxine, compensatory elevation of thyrotropin, and hyperplastic remodeling of thyroid tissue. Such examples show that the pathological consequences of biogenic element deficiency can only be fully understood when chemistry, cell biology, and clinical medicine are considered together.

The aim of this article is to analyze the chemical role of major biogenic elements in the human organism, to describe their physiological functions at the cellular, tissue, and organ levels, and to explain the principal pathological states associated with their deficiency within the logic of an IMRAD-based scientific article.

MATERIALS AND METHODS

The study was carried out using analytical review and comparative interpretation. Scientific information relevant to the topic was systematized from reliable educational and clinical sources in bioinorganic chemistry, medical biochemistry, nutrition science, physiology, endocrinology, and internal medicine. The analysis focused on the chemical form of each element in the body, its transport and distribution, its participation in structural and regulatory processes, and the characteristic biochemical and clinical consequences of deficiency.

Elements were evaluated according to two principal criteria. The first criterion was physiological role, which included structural, catalytic, transport, and regulatory functions. The second criterion was pathological significance, which included early biochemical markers of deficiency, morphological alterations, clinical manifestations, and systemic complications. On this basis, calcium and phosphorus were grouped as key determinants of mineralized tissue formation; magnesium, sodium, and potassium were interpreted as central modulators of bioelectrical stability; iron was analyzed primarily in relation to oxygen transport and hematopoiesis; iodine was discussed as an essential factor in endocrine control; and zinc and selenium were examined mainly through their enzymatic and antioxidant roles.

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The methodological logic of the article was based on three questions for each element: in what chemical form does it operate in the body, through which biological mechanism does its effect become visible, and what pathological picture emerges when deficiency develops. This approach makes it possible to move beyond descriptive enumeration and toward a causal biochemical-clinical interpretation of deficiency states.

Table 1.

Major biogenic elements, their chemical roles, and deficiency-related pathological conditions

Element	Main chemical form or localization	Principal biological role	Typical deficiency-related pathology
Calcium	Hydroxyapatite, ionized Ca^{2+}	Bone mineralization, signaling, coagulation, contraction	Rickets, osteomalacia, tetany, QT prolongation
Phosphorus	Phosphate in ATP, nucleic acids, phospholipids	Energy transfer, membrane structure, buffering	Defective mineralization, weakness, metabolic dysfunction
Magnesium	Mg-ATP complex, intracellular Mg^{2+}	Enzyme cofactor, membrane stabilization, neuromuscular regulation	Cramps, tremor, arrhythmia, refractory hypokalemia
Sodium	Extracellular Na^{+}	Osmotic balance, nerve conduction, fluid distribution	Hyponatremia with confusion, seizures, cerebral edema
Potassium	Intracellular K^{+}	Membrane potential, muscle function, cardiac rhythm	Weakness, ileus, arrhythmias
Iron	Hemoglobin, ferritin, cytochromes	Oxygen transport, redox reactions, hematopoiesis	Microcytic hypochromic anemia, fatigue, cognitive decline
Iodine	Thyroid hormones T_3 and T_4	Endocrine regulation, growth, neurodevelopment	Goiter, hypothyroidism, developmental impairment
Zinc	Metalloenzymes, zinc-finger proteins	Immune function, repair, transcriptional regulation	Dermatitis, growth delay, recurrent infections
Selenium	Selenoproteins, glutathione peroxidase	Antioxidant defense, redox control, thyroid support	Oxidative injury, cardiomyopathy, immune weakness

RESULTS

The results of the analysis show that the role of biogenic elements in the human body becomes visible through three major functional directions: structural support, metabolic catalysis, and physiological regulation. Calcium and phosphorus represent the clearest example of structural and signaling duality. Calcium is the most abundant mineral in the body, and most of it is stored in bones and teeth in the form of hydroxyapatite crystals. However, its role is not limited to the skeleton. In the cytosol calcium acts as a second messenger that transduces hormonal and neurotransmitter

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signals, initiates muscle contraction, contributes to blood coagulation, and modulates membrane excitability. Phosphorus participates in adenosine triphosphate, phosphocreatine, nucleic acids, and membrane phospholipids; it is therefore indispensable for energy metabolism and cellular architecture. Long-standing deficiency of calcium, phosphorus, or their functional partners leads to impaired mineralization, which manifests as rickets in children and osteomalacia or osteopenia in adults.

Magnesium occupies a special place in biochemical energetics. Within the cell, ATP is rarely active as a free molecule and usually functions as the Mg-ATP complex. This means that magnesium is necessary for a large number of phosphorylation reactions and for the normal activity of ATP-dependent enzymes. It also modulates calcium transport, stabilizes excitable membranes, and exerts a physiological restraining effect on neuromuscular transmission. For this reason, hypomagnesemia may present with tremor, increased reflexes, muscle cramps, eyelid twitching, weakness, and ventricular arrhythmias. In practice, magnesium deficiency is frequently accompanied by hypokalemia or hypocalcemia because the homeostasis of these ions is interdependent. The analysis therefore confirms that element deficiency often develops as a network disorder rather than a single isolated abnormality.

Sodium and potassium are the central determinants of cellular bioelectric life. Sodium predominates in extracellular fluid, whereas potassium is concentrated intracellularly. The sodium-potassium ATPase preserves this asymmetry and thereby maintains resting membrane potential, nerve impulse conduction, osmotic stability, and muscle excitability. When potassium becomes deficient, the membrane becomes abnormally hyperpolarized, skeletal muscle weakness appears, gastrointestinal motility decreases, and dangerous cardiac rhythm disturbances may arise. Sodium deficiency, depending on acuity and severity, leads to headache, nausea, confusion, seizures, and cerebral edema. Although sodium and potassium disorders are not always caused by inadequate dietary intake alone, their role as biogenic electrolytes remains fundamental for understanding neuromuscular and cardiovascular physiology.

Iron differs qualitatively from many other essential elements because it possesses variable valence and therefore participates in oxygen binding, electron transport, and redox catalysis. Iron is a core component of hemoglobin, myoglobin, cytochromes, catalase, and multiple iron-sulfur proteins. Its deficiency first reduces body iron stores, then impairs erythropoiesis, and finally produces microcytic hypochromic anemia. At the tissue level, iron deficiency causes cellular hypoxia, fatigue, reduced exercise tolerance, cognitive decline, epithelial changes, hair loss, brittle nails, and in children delayed psychomotor development. The pathological picture is especially important in women of reproductive age, infants, adolescents, and patients with chronic inflammatory or gastrointestinal disorders.

Iodine has an endocrine role of exceptional importance because iodine atoms are indispensable for the biosynthesis of thyroxine and triiodothyronine. These hormones regulate basal metabolic rate, thermogenesis, growth, brain development, and the metabolic activity of almost every tissue. In conditions of iodine deficiency, thyroid hormone production falls and thyrotropin rises as a compensatory response. Persistent stimulation leads to thyroid hyperplasia and enlargement, producing goiter. In severe or prolonged deficiency, hypothyroidism develops, accompanied by fatigue, cold intolerance, bradycardia, constipation, slowed cognition, dry skin, and in children growth and neurodevelopmental impairment. The analysis shows that iodine deficiency is not simply a local glandular problem but a systemic regulatory disorder with pronounced developmental consequences.

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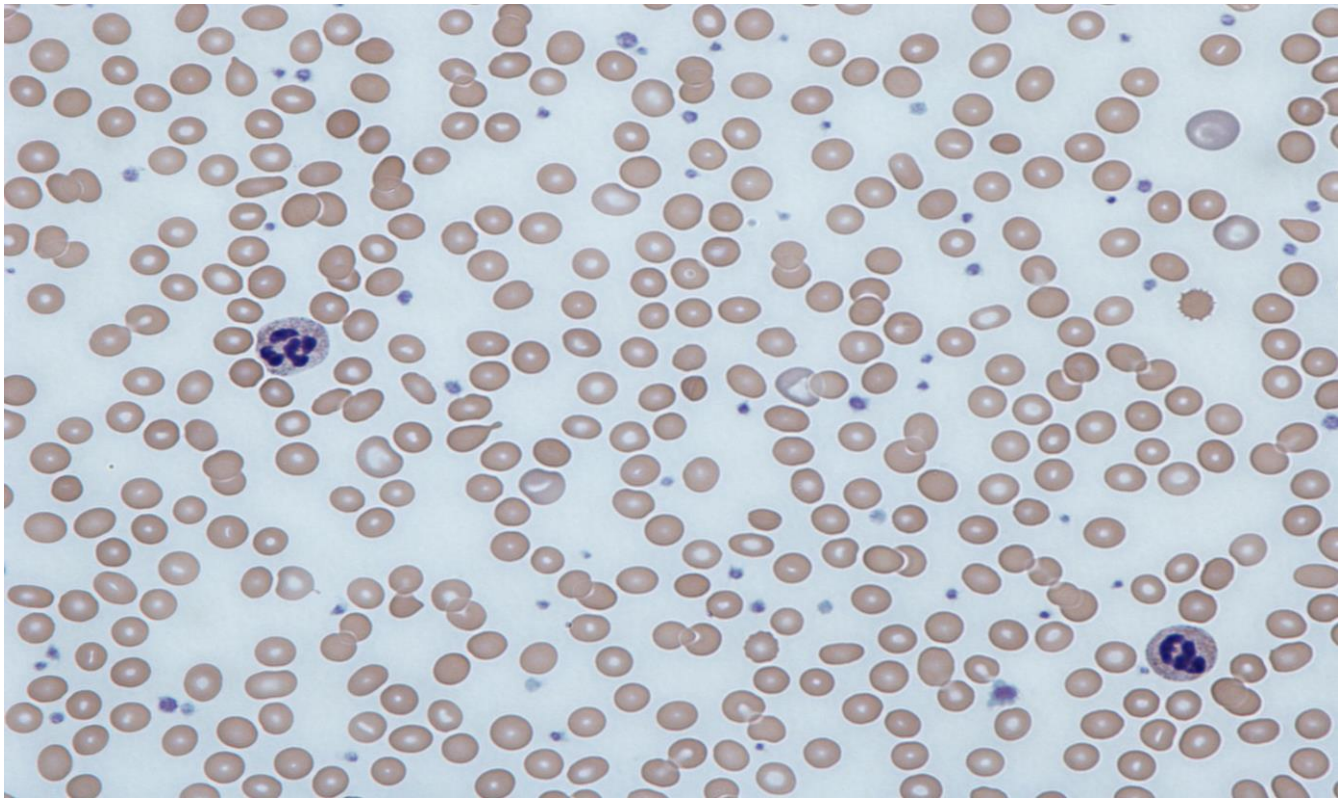
Zinc and selenium, although required in trace quantities, display major biological efficiency. Zinc participates in many metalloenzymes, nucleic acid metabolism, transcription factors, and so-called zinc-finger proteins. It is essential for epithelial integrity, wound healing, reproductive function, immune competence, and normal growth. Zinc deficiency may present with dermatitis, delayed healing, growth retardation, taste disturbance, alopecia, and recurrent infections. Selenium, by contrast, is incorporated into selenoproteins such as glutathione peroxidase and thioredoxin reductase, both of which are central to antioxidant defense and redox signaling. Selenium deficiency weakens cellular protection against oxidative injury and has been linked with cardiomyopathy, thyroid dysfunction, impaired immune responses, and reduced resilience under inflammatory stress. These findings demonstrate that trace elements cannot be regarded as minor simply because they are present in small amounts.



Figure

1. Peripheral blood smear in iron deficiency anemia showing hypochromia and anisocytosis of erythrocytes

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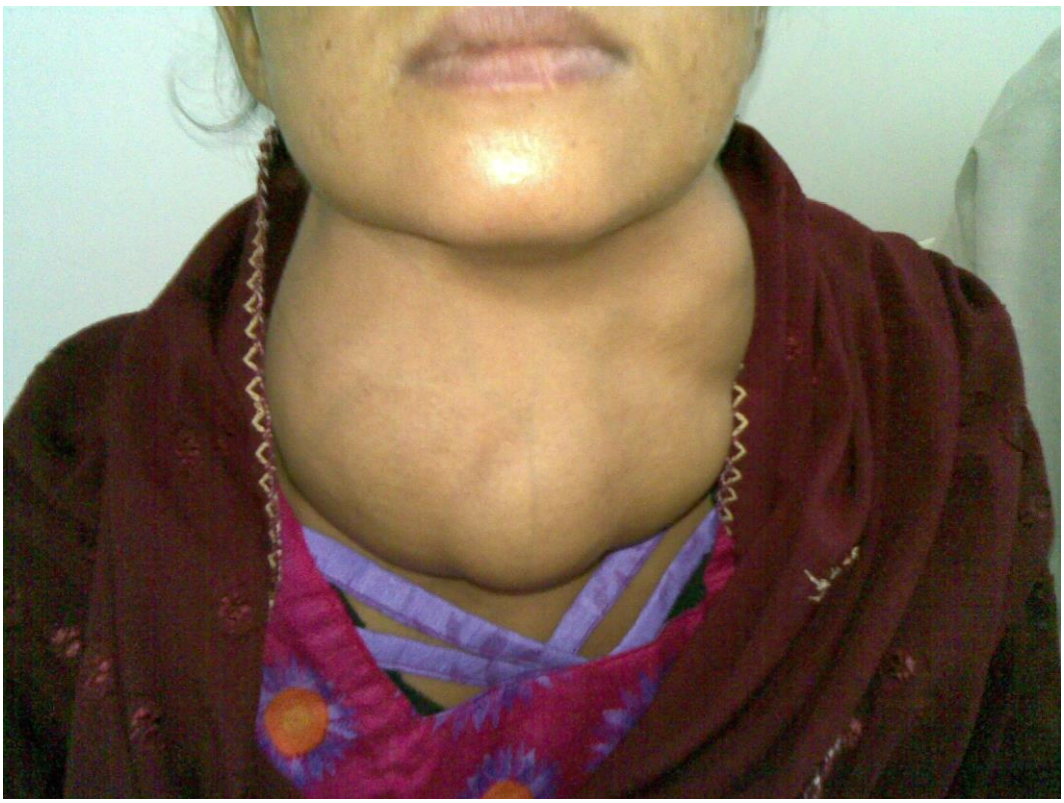

Figure 2.

Clinical appearance of goiter associated with iodine deficiency

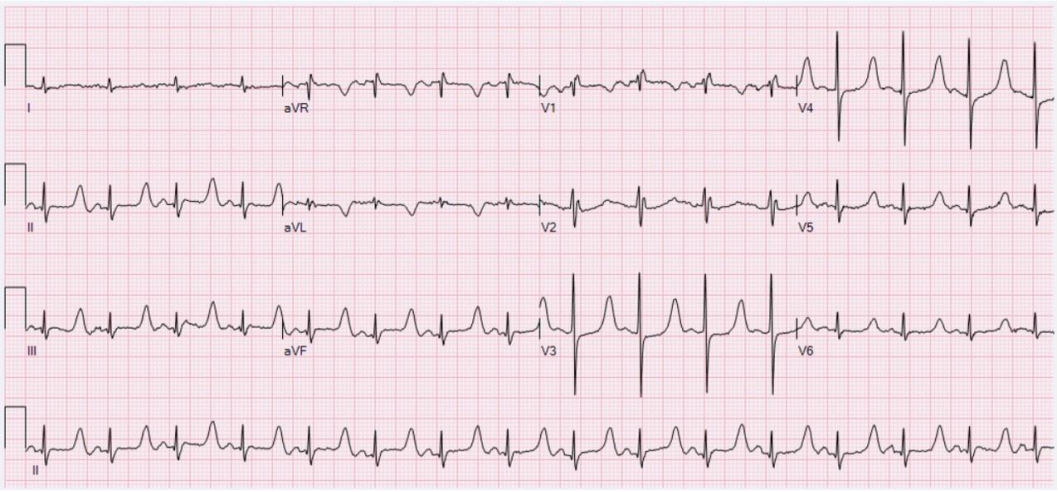

Figure 3.

Electrocardiographic changes in hypocalcemia with ST-segment prolongation and QT interval extension

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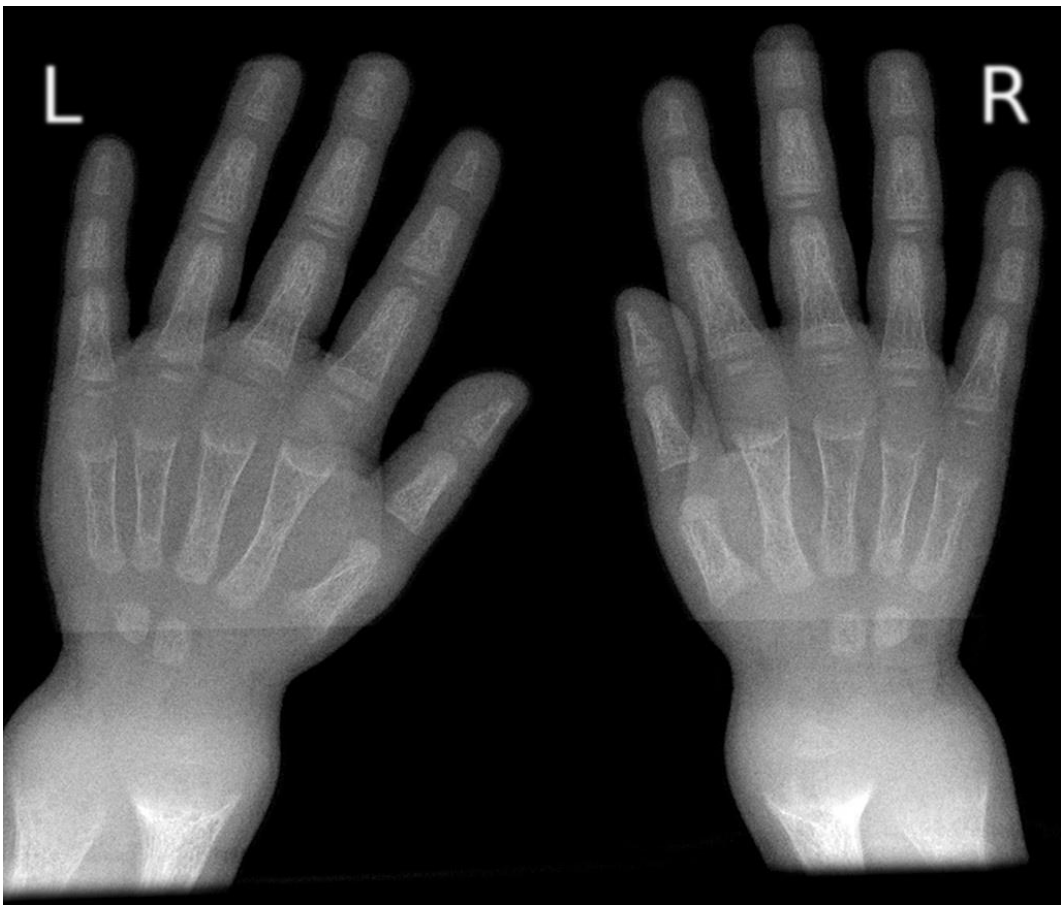

Figure 4.

Radiographic wrist changes in rickets associated with calcium and vitamin D deficiency

DISCUSSION

The findings of this review confirm that deficiency of biogenic elements is rarely confined to a single organ system. The reason lies in the fact that these elements operate within multilayered chemical networks. Calcium deficiency, for example, affects not only bone mineralization but also membrane signaling, coagulation, and neuromuscular excitability. Magnesium deficiency not only compromises ATP-dependent reactions but may also disturb potassium retention and parathyroid hormone regulation, thereby aggravating hypokalemia and hypocalcemia. Iron deficiency primarily presents as anemia, yet its consequences extend to mitochondrial energy production, immune response, epithelial health, and neurocognitive performance. This multidimensionality explains why clinical manifestations are often heterogeneous and why isolated symptom-based treatment is frequently inadequate.

Interactions among biogenic elements are equally important. The ratio of calcium to phosphorus influences hydroxyapatite formation and skeletal stability. Excessive or imbalanced phosphate exposure may aggravate mineral dysregulation when calcium intake is insufficient. Magnesium contributes to the secretion and action of parathyroid hormone and indirectly modulates calcium balance. Iron absorption is improved by ascorbic acid and inhibited by phytates, polyphenols, and some gastrointestinal conditions. Iodine metabolism is affected by environmental exposure, thyroid demand, and population-level salt iodization practices. Zinc and selenium participate in overlapping immune and antioxidant pathways, so deficiency of one may amplify the biological effects of deficiency of the other. For this reason, biogenic element disorders should not be interpreted in isolation.

Another major implication concerns early diagnosis. Clinical signs often appear only after biochemical reserves are already depleted. Ferritin may fall well before overt iron-deficiency anemia emerges. In iodine deficiency, subtle reductions in thyroid hormone economy may precede visible goiter. Magnesium deficiency can remain hidden because serum values do not always reflect intracellular depletion. Calcium disorders may initially manifest through electrophysiological or neuromuscular signs before structural consequences become obvious. Therefore, preventive laboratory assessment, risk stratification, and dietary history are essential, especially in children, pregnant women, older adults, and patients with chronic gastrointestinal, renal, endocrine, or inflammatory diseases.

The practical conclusion of this analysis is that deficiency of biogenic elements cannot be corrected effectively by unsystematic supplementation alone. Rational intervention must include dietary improvement, fortification strategies, evaluation of absorption disorders, treatment of underlying disease, and attention to element-element interactions. From a public health perspective, iodized salt, iron supplementation in high-risk groups, correction of pediatric calcium and vitamin D deficiency, and adequate intake of magnesium, zinc, and selenium remain important preventive measures. From a clinical perspective, the chemistry of each element should guide both diagnosis and therapy. A patient does not suffer from a vague lack of minerals; the patient suffers from the failure of specific chemical systems that support life.

CONCLUSION

Biogenic elements in the human body are not merely structural additives but active determinants of metabolism, membrane transport, hormone biosynthesis, antioxidant defense, bioelectrical stability, and tissue regeneration. Their importance becomes especially clear when deficiency develops and transforms normal physiology into recognizable pathology.

Calcium and phosphorus support skeletal mineralization while also contributing to signaling and energy transfer. Magnesium is indispensable for enzymatic activity and neuromuscular balance. Sodium and potassium preserve membrane potential and excitability. Iron enables oxygen transport and redox metabolism. Iodine ensures thyroid hormone synthesis. Zinc and selenium support catalytic, immune, reparative, and antioxidant systems.

Deficiency of these elements commonly manifests as multisystem disorders such as microcytic anemia, goiter, hypothyroidism, rickets, osteomalacia, tetany, arrhythmias, dermatitis, impaired growth, and immune dysfunction. For that reason, diagnosis should be early and chemically informed, and prevention should combine nutrition, laboratory screening, and targeted public health strategies.

Further research should deepen the study of individual bioavailability, intestinal microbiota interactions, genetic polymorphisms, and combined mineral deficiencies, because these factors may determine why deficiency presents differently among patients exposed to similar nutritional conditions.

REFERENCES

1. Axmedov, A. A. Biochemistry of Macro- and Microelements in the Human Body. Tashkent: Fan, 2018.
2. Karimov, B. R., and Yuldasheva, M. T. The Role of Biogenic Elements in Metabolic Processes. Tashkent: Medicine Publishing House, 2020.
3. Raximov, Sh. S. Clinical Significance of Calcium, Magnesium and Iron Deficiency. Tashkent: Abu Ali ibn Sino Publishing House, 2019.
4. Turaev, H. K., and Eshkaraev, S. C. Chemical Properties of Biogenic Elements and Their Biological Importance. Termez: Termez State University Press, 2021.

JOURNAL OF CHEMISTRY
ISSN(Online): 2984-8075
Volume-9, Issue-01, Published |19-03-2026|

5. Xolmatov, D. X. Human Physiology and Mineral Homeostasis. Tashkent: Yangi Asr Avlodi, 2017.
6. Sobirova, N. A., and Kadirova, D. M. Micronutrients and Their Importance in Human Health. Samarkand: Samarkand State Medical University Press, 2022.
7. Ismoilov, F. U. Iron Deficiency Conditions and Their Prevention. Tashkent: Fan va Texnologiya, 2021.
8. Nurmatov, O. N., and Usmonova, G. S. Biogenic Elements in Medical Practice. Bukhara: Bukhara State Medical Institute Press, 2020.
9. Mamatkulov, R. M. Pathological Conditions Associated with Iodine and Calcium Deficiency. Tashkent: Tafakkur Bo‘stoni, 2019.
10. Eshkoraev, S. S., and Uralov, N. B. The Importance of Mineral Compounds in Biological Systems. Termez: Termez Institute of Economics and Service Press, 2023.
11. Allaberganov, P. K. Bioinorganic Chemistry. Tashkent: University Publishing House, 2018.
12. Rasulova, Z. T., and Tursunov, M. A. Biogenic Elements and Their Role in Enzyme Systems. Tashkent: O‘zbekiston Milliy Ensiklopediyasi, 2021.
13. Kholmurodov, I. E. Medical Chemistry. Tashkent: Lesson Press, 2016.
14. Shodiev, E. B., and Muxitdinova, N. R. Deficiency of Essential Elements and Related Disorders in Children. Andijan: Andijan State Medical Institute Press, 2022.
15. Yusupov, A. A. Fundamentals of Biological Chemistry. Tashkent: Teacher Publishing House, 2017.
16. Boboev, S. T., and Saidova, L. M. The Biological Effectiveness of Macro- and Microelements in the Human Organism. Navoi: Navoi State Pedagogical Institute Press, 2023.