International Journal of Advances in Engineering and Management (IJAEM)
Volume 7, Issue 08 Aug. 2025, pp: 69-73 www.ijaem.net ISSN: 2395-5252

Soil Environment and Human Health: The Importance of Trace Element Balance

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Date of Submission: 25-07-2025 Date of Acceptance: 05-08-2025

ABSTRACT: Soil, a crucial natural resource for human survival, not only provides a solid foundation for agricultural production but also transfers trace elements to the human body through the food chain, exerting a profound influence on our health conditions. In this article, we will explore the multi-faceted harms to human health caused by the imbalance (deficiency or excess) of common trace elements in soil such as iron, zinc, copper, selenium and iodine, and briefly explain their mechanisms of action. By implementing scientific and reasonable soil management strategies and making appropriate dietary adjustments, we can effectively address the imbalance of trace elements, thereby ensuring human health and promoting plant growth. In addition, this article will also analyze the influence of soil trace elements on plant growth, with the aim of enhancing public awareness of the importance of soil health, promoting scientific and reasonable soil management practices, and improving personal health awareness.
Keywords: soil,trace elements, human health, plant growth, countermeasures

I. INTRODUCTION

Healthy soil is the foundation of life. The human body absorbs trace elements from the soil through the food chain. Although these trace elements are present in tiny amounts in the human body, they play an irreplaceable and crucial role in maintaining human health (Lietal., 2023). Meanwhile, these trace elements are also essential for plant growth, as they participate in various physiological processes of plants and affect crop yield and quality. However, due to inherent geographical conditions and the development of industry and agriculture, as well as worsening environmental pollution (Campos and Mardones, 2023; Alloway, 2013), not only has plant growth been severely damaged, but the balance of trace elements in the human body has been disrupted after they enter the food chain, thereby posing a threat to human health.

II. THE ROLE OF TRACE ELEMENTS IN THE HUMAN BODY

Trace elements required by the human body include iron, zinc, copper, selenium, iodine, etc., which are involved in various physiological functions such as enzyme catalytic reactions, immune system maintenance, and antioxidant effects (Lietal., 2023) .

Iron Iron is a crucial component of hemoglobin, which is responsible for transporting oxygen from the lungs to various parts of the body. Iron also plays a role in energy metabolism and immune system function. Iron deficiency can lead to anemia, making people prone to fatigue and difficulty concentrating. For example, according to World Health Organization data, the infertile soil in certain regions of Africa has led to long-term iron deficiency among local residents, resulting in widespread anemia(Daniela et al., 2016). This has affected children's learning abilities and adults' work efficiency, with anemia rates reaching over 50%. In a study in sub-Saharan Africa, 1000 children were tested and 70% were found to have varying degrees of iron-deficiency anemia, seriously impacting their cognitive development and daily activity abilities. A specific case is in a village in Ethiopia, where many children cannot attend school regularly due to iron-deficiency anemia. They frequently experience dizziness and fatigue, leading to significant declines in their academic performance.

Zinc Zinc is a key element for maintaining the normal functioning of the immune system. It participates in various enzyme catalytic reactions and is particularly important for children's growth and development. Zinc deficiency can affect children's growth and development, reduce immunity, and lead to slow wound healing. In some regions of South Asia, due to zinc deficiency in soil, local children experience growth retardation, low immunity, and are prone to infections. According to research, zinc-deficient children's weight and height are on average 20% lower than the standard for children of the same age. For example, in a survey conducted in

India, 500 children under 5 years old were tested, and it was found that 45% of them were zinc deficient. These children's weight and height were significantly lower than normal standards, and the incidence of respiratory infections and diarrhea was significantly higher than that of children with adequate zinc. In a rural area of Bangladesh, the problem of zinc deficiency is particularly severe. Many children frequently fall ill due to low immunity and slow growth and development, affecting their future.

CopperCopper is a component of various enzymes in the body, participating in iron metabolism, bone development, and normal nervous system function. However, excessive copper can also have negative effects. Excessive copper can damage the liver, potentially leading to cirrhosis and liver failure. In some copper mining areas, the excessive copper content in soil and water sources, and the prevalence of liver disease is relatively high in this region. Research data shows that the liver disease incidence in these areas is more than three times higher than normal areas. For example, in a copper mining area in Chile, a health check was conducted on 1,000 local residents, and it was found that 30% of them suffered from varying degrees of liver disease (Bost et al., 2016; Liu et al., 2024), while the liver disease incidence rate in neighboring non-copper mining areas was only 10%. Specifically, in some villages in this area, many residents' liver function has gradually declined due to long-term consumption of copper-contaminated food and water, seriously affecting their quality of life and lifespan.

SeleniumSelenium has powerful antioxidant properties that protect cells from oxidative damage. It also participates in thyroid hormone metabolism. Selenium deficiency increases the risk of cardiovascular diseases and cancer, and affects thyroid function. Keshan disease is a type of cardiomyopathy caused by selenium deficiency, which once prevailed in some selenium-deficient areas in China, with an incidence rate as high as 10% in these areas (Rayman, 2000; Loscalzo, 2014)]. For example, in a health survey conducted among 2,000 residents in a selenium-deficient area in Northeast China, 200 people were found to suffer from Keshan disease, and their serum selenium levels were significantly lower than normal. In a rural area of Heilongjiang Province, patients with Keshan disease often experienced chest tightness and palpitations, seriously affecting their labor capacity and daily life. However, excessive selenium intake can also lead to selenium poisoning, manifested as hair loss, nail deformities, and nervous system damage. Residents in some selenium-rich areas in the United States have developed selenium poisoning symptoms due to excessive selenium intake, with the poisoning rate reaching as high as 30% in some villages. For instance, in a selenium-rich area of Wyoming, a survey of 500 local residents found that 150 people showed symptoms of selenium poisoning, mainly hair loss and nail deformities. In some towns in this area, residents have developed widespread selenium poisoning due to long-term consumption of selenium-rich agricultural products, seriously affecting their appearance and health.

IodineIodineis an essential component for thyroid hormone synthesis, which plays a crucial role in the body's metabolism, growth, and development. Iodine deficiency can lead to goiter and affect children's intelligence and growth. In some mountainous areas, due to iodine deficiency in soil and water sources, the incidence of goiter among local residents is in high rate, and children's intellectual development is also affected. The average IQ of children in iodine-deficient areas is 15-20 points lower than that in normal areas(Higuchi, 2015). For example, in a study conducted in a mountainous area in southwestern China, 1000 children were tested, and it was found that 40% of them suffered from goiter, and their average IQ was 18 points lower than that of children in neighboring iodine-sufficient areas. In a mountainous area of Yunnan Province, many children have delayed intellectual development due to iodine deficiency, resulting in poor academic performance, which affects their future.

Excessive iodine intake may lead to hyperthyroidism, causing symptoms such as palpitations and weight loss. In some coastal areas of Japan, due to excessive consumption of iodine-rich seafood, the incidence of hyperthyroidism is in high rate, twice the national average incidence. For example, in a coastal area of Hokkaido, Japan, a health check was conducted on 1000 local residents, and it was found that 20% of them suffered from hyperthyroidism, while the national average incidence rate was only 10%. In some fishing villages in this area, residents have developed hyperthyroidism due to long-term excessive iodine intake from seafood, causing palpitations and sweating, which affects their daily life and work.

III. THE ROLE OF TRACE ELEMENTS IN PLANT GROWTH

Trace elements required by plants include iron, zinc, copper, manganese, boron, molybdenum, etc., which have significant impacts on plant growth, development, yield and quality.

Iron is an essential element for chlorophyll synthesis in plants. Iron deficiency can lead to leaf

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yellowing and affect photosynthesis (Osendarp and Eilander, 2014; Stephen et al., 2025; Paganini et al., 2016). In some alkaline soils, iron easily forms insoluble compounds, leading to iron deficiency in plants. For example, in some alkaline soil areas in northern China, fruit trees show leaf yellowing, which seriously affects their yield and quality. According to research, fruit tree yields in these areas have decreased by an average of 30%.

Zinc is involved in plant auxin synthesis and photosynthesis. Zinc deficiency can lead to slow plant growth and smaller leaves. In some sandy soils, zinc is easily lost, resulting in plant zinc deficiency. For example, rice grown in sandy soils in some areas of South Asia suffers from zinc deficiency widespread, with significant declines in both yield and quality. Research shows that zinc-deficient rice yields are 25% lower than normal rice yields.

Copper is a component of various enzymes in plants, participating in photosynthesis and respiration. Excessive copper can be toxic to plants, leading to growth inhibition and leaf wilting (Bost et al., 2016; Liu et al., 2024). In some farmlands near copper mines, the high copper content in soil has caused crops to wilt, resulting in significant yield reductions. For example, crop yields in farmlands near a copper mine in Chile have decreased by 40% (Bost et al., 2016).

Manganese participates in plant photosynthesis and nitrogen metabolism. Manganese deficiency can lead to leaf spotting and impaired photosynthesis. In some acidic soils, manganese is prone to excess, leading to manganese toxicity in plants (Lottermoser, 2010). For example, in some acidic soil areas in southern China, tea plants have shown manganese toxicity, affecting tea quality. Research shows that the quality of manganese-toxic tea has decreased by 20%.

Boron is an essential element for plant pollen germination and fruit development. Boron deficiency can lead to poor flowering and fruiting in plants (Lottermoser, 2010; Jiang et al., 2025). In some calcareous soils, boron is easily fixed, leading to boron deficiency in plants. For example, in some calcareous soil areas in Northwest China, cotton plants have shown poor flowering and fruiting, seriously affecting cotton yields. According to statistics, cotton yields under boron deficiency are 35% lower than normal cotton yields.

Molybdenum is a key element in plant nitrogen fixation. Molybdenum deficiency can lead to slow plant growth and chlorosis. In some infertile soils, the low molybdenum content results in plant molybdenum deficiency (Atwal and Scaglia, 2016; Lottermoser, 2010). For example, in some infertile soil areas of Africa, molybdenum deficiency is common in legume crops, leading to low yields. Research shows that the yield of molybdenum-deficient legume crops is 30% lower than normal yields.

IV. THE IMPACT OF SOIL TRACE ELEMENT IMBALANCE ON HUMAN HEALTH

4.1 Effects of trace element deficiency

Iron deficiency: Leads to anemia, affects oxygen transport, and causes fatigue and difficulty concentrating. For example, in some areas of Africa, the infertile soil leads to long-term iron deficiency among local residents, resulting in widespread anemia. This has impacted children's learning abilities and adults' work efficiency, with anemia rates reaching over 50% (Stephen et al., 2025).

Zinc deficiency: Impairs children's growth and development, weakens immune system, and slows down wound healing. In some regions of South Asia, due to zinc-deficient soil, local children experience stunted growth and development, low immunity, and are prone to infections. The weight and height of zinc-deficient children are on average 20% below the standard for their age group.

Selenium deficiency: Increases the risk of cardiovascular diseases and cancer, and affects thyroid function. Keshan disease, a type of cardiomyopathy caused by selenium deficiency, once prevailed in some selenium-deficient areas in China, with an incidence rate of up to 10% in these areas(Loscalzo, 2014; Han et al., 2025).

Iodine deficiency: Causes goiter and affects children's intelligence and growth development (Higuchi et al., 2015). In some mountainous areas, due to iodine deficiency in soil and water sources, the incidence of goiter among local residents is relatively high, and children's intellectual development is also affected. The average IQ of children in iodine-deficient areas is 15-20 points lower than that in normal areas.

4.2 Effects of Excessive Trace Elements

Excessive copper: Damages the liver and may lead to cirrhosis and liver failure. In some copper mining areas, there is excessive copper content in soil and water sources, resulting in a higher incidence of liver diseases among local residents. Research data shows that the liver disease incidence in these areas is more than three times higher than normal areas(Campos and Mardones, 2013).

Selenium Overdose: Leads to selenium toxicity, manifesting as hair loss, nail deformities, and nervous system damage. Residents in some selenium-rich areas of the United States have experienced selenium toxicity symptoms due to excessive selenium intake, with poisoning rates reaching as high as 30% in some villages.

Iodine excess: Can lead to hyperthyroidism, causing symptoms such as palpitations and weight loss (Higuchi et al., 2015). In some coastal areas of Japan, due to excessive consumption of iodine-rich seafood, the incidence of hyperthyroidism is significantly higher, twice the national average.

V. STRATEGIES FOR ADDRESSING SOIL TRACE ELEMENT IMBALANCE

The imbalance of soil trace elements is caused by multiple factors (Alloway, 2013). First, natural factors such as inherent differences in soil composition across different regions lead to uneven distribution of trace elements. Second, human activities including heavy metal and chemical pollution from industrial emissions, overuse of fertilizers and pesticides that damage soil structure, and mining activities which release large amounts of trace elements into the environment, all contribute to soil trace element imbalance.

We can improve soil environment through proactive strategies and methods to address soil micronutrient imbalance.

5.1Soil improvement

Enhancing soil structure and fertility, as well as increasing the availability of trace elements through the application of organic fertilizers and biochar.

5.2Scientific fertilization technology

According to soil test results, chemical fertilizers and trace element fertilizers should be applied reasonably to avoid overuse. "Green & Health" organic fertilizer is produced through modern fermentation and other processing techniques by using organic materials such as mushroom residue, cow manure, and earthworm castings.It specifically adds trace elements and forms organic trace element nutrient fertilizer through the chemical reaction process of fermentation. This fertilizer plays a significant role in improving soil structure and addressing trace element deficiencies, while enhancing plants disease resistance, increasing essential trace elements in fruits, and improving fruit yields.

5.3 Pollution control

Strengthen the management of industrial emissions and agricultural chemicals to reduce soil pollution. Hyperaccumulator plants, such as Sedum alfredii, have strong remediation effects on heavy metal-contaminated soil including copper, lead, zinc, and cadmium. Planting Sedum alfredii in contaminated areas can significantly reduce heavy metal pollution in soil (Liu et al., 2025; Zhang et al., 2025). Large-scale cultivation helps reduce the application of chemical fertilizers, thereby minimizing the introduction of harmful trace elements (Zhu et al., 2022; Ju et al., 2016).

5.4 Maintain a diverse diet

By maintaining a diversified diet and obtaining trace elements from various food sources, we can avoid trace element imbalances caused by a single food source.

5.5 Regular monitoring

Establish a monitoring system for trace elements in soil and agricultural products, and timely detect and address trace element imbalances.

VI. CONCLUSION

The balance of soil trace elements is crucial for both human health and plant growth. Through scientific soil management and dietary adjustments, we can effectively address trace element imbalances, ensuring human well-being and plant growth. Governments, research institutions, farmers, and the public should work together to raise awareness of soil health and promote sustainable development.

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