

Effect of Boron Mineral on Health

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ABSTRACT

Boron is a mineral that plays important roles in humans, animals and plants. However, the exact mechanism by which this mineral performs its functions in humans and animals is not fully understood. As a result, it is not classified as an essential element for humans and animals. People and animals live in the areas of Eskişehir, Kütahya, Bursa and Balıkesir provinces that have been boron resources for thousands of years. The total reserves in Türkiye have been estimated at 3.3 million tonnes. The water that comes from these provinces is consumed by the plants, vegetables, fruits and animals that feed on the plants grown here and by humans who consume them as food. It is an important mineral that has been consumed continuously with plants, animal products and water since the existence of our country. It is found in very high concentrations in precious foods such as dates, plums, grapes, almonds, hazelnuts, peanuts and honey. Many studies carried out in countries without boron resources and using high doses of boron have led to it being included in the group of toxic minerals. The mineral boron, which is important in terms of dosage and duration of use, and which we believe is present in physiological foods and which we are trying to clarify with our studies, is one of the essential trace elements. The benefits of boron mineral to living organisms have been demonstrated in many studies to date. However, it is a promising mineral that needs to be supported by further biological studies.

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INTRODUCTION

Boron is a naturally occurring element that exists as borates in oceans, coal, shales, sedimentary rocks, and various soils. It is widely found in nature, with an average concentration of approximately 10 mg/kg in the Earth's crust. (WHO, IPCS, 1998). Boron is a ubiquitous element present in rocks, soil, and water. While most soils globally contain less than 10 ppm of boron, elevated concentrations are observed in certain areas, particularly in parts of the western United States and regions stretching from the Mediterranean to Kazakhstan (Shorrocks, 1997; DPT, 2001).

The average concentration of boron in soil is typically in the range of 10 to 20 ppm and boron deficiency exists in large areas of the world. Economically significant boron mineral deposits, which always occur as oxygen-bound boron compounds, are rare and are generally found in arid regions with a history of volcanic or hydrothermal activity. These deposits are actively mined in Türkiye, the United States and various other countries (Matterson, 1980). In Türkiye, which has 73% of the world's boron reserves (Table 1), major deposits are found at Bursa-Kestelek, Eskişehir-Kırka, Kütahya-Emet and Balıkesir-Bigadiç (Eti Maden, 2024).

Table 1. Distribution of world boron reserves (Tenmak, 2017)

Country	Total Reserve (Thousand tons B ₂ O ₃)	Total Reserve (% B ₂ O ₃)
Türkiye	948712	73.4
Russia	100000	7.7
U.S.A	80000	6.2
Chile	41000	3.2
China	36000	2.8
Peru	22000	1.7
Serbia	21000	1.6
Bolivia	19000	1.5
Kazakhstan	15000	1.2
Argentina	9000	0.7
Total	1310300	100

Studies on boron in both animals and humans have shown that approximately 90% of orally ingested boron is absorbed (Trumbo et al., 2001). Boron is mainly excreted in the urine, with a smaller proportion excreted in the faeces (2%) and minimal amounts excreted in the breath, sweat and bile. Studies in animals show that boron does not accumulate significantly in soft tissues; rather, it concentrates much more in bone than in blood or other soft tissues. (Moseman, 1994).

In a 2009 screening of boron in the Polatlı region, it was found that boron was found in chamomile at 8.41 ppb; in water at 1.94; 2.02; 2.26; 2.33; 2.42; and in milk at different dairy farms at 0.74; 4.13; 4.97 ppb (ug/L).

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Many studies have shown the benefits of boron mineral in living organisms in bone development, brain function, macro mineral metabolism, reproduction, energy substrate utilisation, immune function, cardiovascular health and insulin secretion, and even anti-aging effects.

A deficiency in boron has been linked to weakened immune function and a higher prevalence of osteoporosis, which can elevate the risk of mortality. Conversely, excessive boron intake may lead to cellular damage and toxicity in both humans and various animal species. Recent studies have explored the diverse effects of boron, including its role in immune system activation, support for antioxidant detoxification, influence on bone metabolism, enhancement of animal performance, and regulation of multiple physiological systems. Additionally, boron has been recognized as an agent that mitigates heat stress in plants, with similar benefits proposed for animals. In addition, boron supplementation in dairy cows has been found to induce significant changes in liver metabolism (Abdelnour et al., 2018).

A review of studies in both animals and humans suggests that boron may play a vital role in the hydroxylation of steroid rings. This is based on the hypothesis that boron affects the metabolism of various nutrients and steroid hormones, including 1,25(OH)₂ vitamin D, 17- β -estradiol, and testosterone. This function becomes especially significant when dietary intake of vitamin D, magnesium or both is insufficient (Rondanelli et al., 2020).

Boron affects the activity of at least 26 different enzymes, many of which are essential for the metabolism of energy substrates (Hunt, 1998). Boron's unique chemical properties allow it to interact with various metabolites and enzymes, which can affect mineral and energy metabolism in both humans and animals (Deviran and Volpe, 2003). In addition, boron plays a regulatory role in the metabolism of several essential minerals, including phosphorus, magnesium and calcium (Wilson and Ruszler, 1996).

The most studied effect of boron on health is its effect on bone development. Boron is essential for osteogenesis, and its deficiency has been shown to negatively affect bone growth and regeneration (Demirer et al., 2012). In addition, boron improves the utilisation of vitamin D. Research has shown that boron supplementation can promote bone growth in animals suffering from vitamin D deficiency and help alleviate the mineral metabolism disorders associated with this deficiency (Hunt, 1994).

The effects of boron on reproduction are the most debated areas of toxicity. Boron was once classified in the EU as a reproductive toxic mineral in labelling, packaging and classification. Claims that boron is reproductive toxic have been supported by animal toxicity studies.

Although epidemiological studies conducted in later years in communities in countries with high boron exposure, such as our country and China (Duydu and Üstündağ, 1994; Scialli et al., 2010; Yalçın et al., 2019), have shown that boron does not harm reproduction, this perception still persists and other benefits of boron in living organisms are ignored. In addition, unlike the animal toxicology studies conducted in the past with limited resources, there are studies in animals that have used boron and examined its effects on reproductive function. These studies have found that boron improves semen quality and enhances reproduction (Armstrong et al., 2002; Elkomy et al., 2015; El-Sadany, 2017; Ibrahim et al., 2019; Krishnan et al., 2019).

It has been reported in studies that boron causes changes in immune response, including inflammatory processes. In this context, a study examining the effects of boron on immune function found that boron acts as a regulator of immune and inflammatory responses, as well as macrophage polarization. This strengthens the role of boron in enhancing both innate and adaptive immunity, with potential implications for cancer and other diseases (Routray and Ali, 2016). Additionally, another study indicated that food-appropriate boron supplementation can serve as an immune regulator for both humans and animals (Jin et al., 2017).

A study investigating the relationship between insulin metabolism and boron indicated that exposure to borax reduces blood lipid levels (Basoglu et al., 2000). Moreover, research has shown that

a lack of boron raises the insulin requirements necessary to sustain plasma glucose levels when vitamin D and magnesium nutrition is inadequate in chicks and rats (Bakken and Hunt, 2003). Furthermore, dietary boron supplementation has been shown to decrease body weight, leptin, and insulin levels while increasing plasma T3 levels, thereby enhancing the metabolic activity of rats (Kucukkurt et al., 2015).

Research also suggests that boron may influence cardiovascular health. One study highlights the potential role of boron-containing compounds in regulating signalling pathways associated with inflammation, oxidative stress and lipid metabolism. The potential cardioprotective effects of these compounds provide new and exciting opportunities for their use in dietary supplements and possibly pharmaceuticals (Donoiu et al, 2018).

To further explore boron's functional role, researchers conducted additional studies on brain electrophysiology and cognitive performance in response to dietary boron manipulation among healthy older men and women. The results indicated that low dietary boron intake significantly impaired performance in a variety of cognitive and psychomotor tasks, particularly those emphasizing manual dexterity, compared to high boron intake. Overall, the findings from these studies indicate that boron might be crucial for human brain function and cognitive performance, offering further proof of its importance as an essential nutrient for humans (Penland, 1994).

Five studies examining electrical brain activity in both animals and humans have found that boron deficiency leads to reduced electrical brain activity, similar to the effects of general malnutrition. Furthermore, evaluations of cognitive and psychomotor function in humans indicate that boron deficiency is associated with reduced performance in tasks involving motor speed, attention, dexterity, and short-term memory. These findings emphasize the significance of boron supplementation in supporting brain function and mental health (Penland, 1998).

In appropriate nutritional doses, boron supports bone strength and cognitive function, regulates immune and inflammatory responses, and impacts the body's reaction to oxidative stress. Its diverse effects appear to stem from its influence on cellular signaling pathways or its role in the formation and function of key biochemical components. Research from both human and animal studies suggests that a daily boron intake of around 1.0 mg could be sufficient to ensure its beneficial effects (Nielsen, 2017). Insufficient boron levels have been associated with weakened immune function, increased mortality risk, osteoporosis, and cognitive impairment. On the other hand, excessive boron intake has been linked to cellular damage and toxicity in both humans and various animal species (Haliq et al., 2018).

According to a 2023 study, boron-containing compounds have shown effects on neurons, with new boron-containing compounds being synthesised and their effects on neuronal activity reported. These compounds exert their effects by modulating inflammation and oxidative processes. The study highlights the intention to investigate the use of boron-containing compounds as targeted drugs for the treatment of neurodegenerative diseases in future research (Barrón-González et al., 2023).

Research into the role of boron in supporting healthy living and longevity is limited but promising. Boron has bioactive properties that influence the formation and activity of NAD⁺ and S-adenosylmethionine (SAM), both of which are associated with ageing and longevity. Evidence suggests that boron has beneficial effects on oxidative stress, inflammatory responses, DNA damage detection and repair, and the role of SAM in methylation and regulation of homocysteine levels. These effects suggest that adequate boron intake may alleviate several age-related pathological conditions, cognitive decline, including cancer, sarcopenia and bone health. Therefore, a boron-rich diet could support healthy ageing and longevity (Nielsen, 2018).

In addition, boron compounds and complexes other than boric acid and its salts are used for skin rejuvenation. These compounds have demonstrated benefits in reducing wrinkles, increasing skin thickness, improving hydration, softness and elasticity, improving skin tone and minimising the number and size of age spots. These compounds are often formulated in appropriate solvent systems, such as microemulsions or macroemulsions, and can be applied in various forms, including creams, bath salts, cosmetics and shampoos (Miljkovic and Pietrzkowski, 2000). Moreover, the findings indicate that boron supplementation enhances bone strength and improves the microstructure of both cortical and trabecular bone in diabetic animals as well as in supplemented control groups (Dessorti et al., 2017).

CONCLUSION

Boron is a mineral that has long been used in agriculture as a fertiliser and pesticide, and is also used in insulation and building materials, glass, cement, metal and defence industries. Humans and animals regularly receive boron through their daily diet. However, information on the biological effects of this element is still limited.

Despite the numerous studies conducted in recent years on the effects of boron and its mechanisms of action, further research is required to fully elucidate its effects and the underlying mechanisms by which it acts in living organisms. It is known that this mineral acts on many enzymes and enzyme systems, affecting fat and lipid metabolism, mineral metabolism and vitamin D, as well as having benefits for bone development, the immune system, cardiovascular health and even healthy ageing and longevity. Although much of the current research and information on boron is useful, much more is needed.

Although the benefits of boron are known and supported by studies, the toxicity studies conducted with very high doses of boron in the past are still valid today, and the claims that boron is toxic and the perception that is being created should be removed with the studies that will be conducted.

In Türkiye, which has 73% of the world's boron reserves, work in this area is unfortunately below what it should be. In America, which has about 7% of the world's reserves, the boron market is much more developed and its use in the health sector is much higher. In addition, the production of high value-added boron products should be increased and their use promoted.

In our country, which is the world's repository of this valuable mineral, whose use should be much greater in the future, further research and support of the use of boron and its benefits to living organisms with studies will be beneficial to our country and world in terms of both health and economy.

Ethical Statement

This is a review article and does not necessarily need ethics approval.

Author Contributions

Data Collection (CRediT 2) Gültekin YILDIZ (%100)

Research - Data analysis - Validation (CRediT 3-4-6-11) Gültekin YILDIZ (%100)

Writing the Article (CRediT 12-13) Gültekin YILDIZ 1 (%100)

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Conflict of Interest

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3 Good Health and Well-Being

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