ID: 739

Nutritional and Health Implications of Some Essential and Non-Essential Elements in Edible Salts Commonly Consumed in Türkiye

Özlem Üstün-Aytekin[1*], Rüya Kuru-Yaşar[1], Şahin Yılmaz[2], Fikrettin Şahin[2]

[1]Department of Nutrition and Dietetics, Hamidiye Faculty of Health Sciences, University of Health Sciences, Istanbul, Türkiye
[2]Department of Genetics and Bioengineering, Faculty of Engineering, Yeditepe University, Istanbul, Türkiye
*ozlem.aytekin@sbu.edu.tr
*Corresponding Author: Özlem Üstün-Aytekin
Address: Selimiye Mahallesi Tibbiye Caddesi No:38 34668 Uskudar, Istanbul

Abstract

Salt is a daily staple food and an important source of minerals. However, contamination in salt can pose public health risks. This study aimed to determine the concentrations of essential (calcium, potassium, magnesium, iron, manganese) and non-essential elements (aluminum, boron, chromium, nickel) in 11 commonly consumed edible salts in Türkiye and evaluate their potential health risks and nutritional contributions. The element levels were determined using Inductively Coupled Plasma Mass Spectrometry (ICP-MS), health risk assessments were conducted, and the percentage contributions of the elements to daily dietary reference values were calculated. Element levels varied significantly among samples. For instance, aluminum levels ranged from 0.13 to 5.60 mg/kg. The highest calcium, potassium, magnesium, aluminum, iron, manganese, and nickel levels were found in S5 (Himalayan salt), while chromium was highest in S9 (rock salt). Hazard index values remained below the safety threshold, and all salts were evaluated as low risk. Although the risk assessment suggests no immediate threat based on the current data, the necessity for comprehensive element analyses of edible salts remains crucial. Moreover, despite the variations in mineral levels, the assessed salts are unlikely to meet the recommended daily intake levels for essential minerals.

Key Words: *Salts; Elements; Public health; Risk assessment; Food contamination*

Introduction

Salt is an essential source of minerals required by humans and is utilized in various industries, including metallurgy, textile, medicine, agriculture, and chemicals (Horasan and Öztürk, 2021). Table salt is commonly added to enhance the flavor of foods and serves as a preservative for many canned, salted, pickled, and fresh foods (Elias et al., 2020; Nagendra et al., 2020). While salt exists in liquid form in seas, lakes, and other water sources, it is classified as rock salt in its solid form. The sea is the largest global source of salt, with its salt content influenced by geographical structures, physical and chemical changes in rocks, evaporation, and climatic conditions. In Türkiye, raw salt production occurs from seawater, underground rock mining, lake water, and underground spring water (Türkiye Mineral Research and Exploration General Directorate, 2023).

Elements can be examined in two groups, essential and non-essential when evaluating their effects on human health (Demir et al., 2020). Essential elements have important functions in the human body, but they can be toxic at high consumption rates. However, essential elements have homeostatic mechanisms that increase or decrease absorption and excretion to maintain certain levels in the body. Insufficient essential element intake results in deficiency symptoms, while high intake can be toxic to metabolisms (Somuncu et al., 2025). On the other hand, non-essential elements have no known function in the human body, they can be toxic even at low concentrations and cause health problems. Long-term exposure to non-essential elements can lead to physical (i.e. blood pressure changes, changes in blood composition, chronic pain, etc.) and psychological (i.e. anxiety, passivity, etc.) disorders, neurodegenerative diseases, and cancer (Witkowska et al., 2021; Marquès et al., 2022; Jomova et al., 2024). The severity of their health impacts depends on several factors the dose, the route and the duration of exposure, and the degree of bioaccumulation in the body (Ali et al., 2018).

Since salt is a substance consumed daily, any contamination can have adverse effects on consumer health. The natural resources from which salt is obtained may sometimes contain high levels of essential and non-essential elements. These increased levels can adversely affect human health. Furthermore, industrial waste, pesticides, and other contaminants can increase the element levels in these sources (Lugendo and Bugumba, 2021). Factors such as the equipment and energy sources used in salt production, air, and water pollution in regions near salt beds, and the processing and packaging of salt can also contribute to its essential and non-essential element content (Chan et al., 2021; Di Salvo et al., 2023).

The World Health Organization (WHO) (2024) recommends a daily salt intake of less than 5 grams. However, the average daily salt consumption in Türkiye is around 10.2 g among individuals aged 15 and older (Republic of Türkiye Ministry of Health, 2019). The consumption of high salt content foods such as pickles, olives, cheese,

fermented cereal foods like tarhana and bread, along with a preference for salty flavors, may contribute to the elevated salt consumption in Türkiye. Despite public health campaigns, the slow adoption of salt reduction initiatives in food manufacturing and daily consumption practices contributes to continued high intake (Erdem et al., 2017). Therefore, the risk of people living in Türkiye being exposed to elements from edible salts is higher.
This study aims to determine the levels of some essential (calcium, potassium, magnesium, iron, manganese) and non-essential elements (aluminum, boron, chromium, nickel) in 11 different table salt products mostly consumed in Türkiye, employing the Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) method. Additionally, the findings are evaluated in the context of public health and nutrition.

Materials and Methods

Samples
A total of eleven different types of salt were analyzed, including three Himalayan salts, three rock salts, three spring salts, and two sea salts, all commonly consumed in Türkiye. Detailed information regarding the salt types and their origins is given in Table 1.

Analysis by ICP-MS method
0.3 g of each salt was weighed and dissolved in a mixture of 10 mL of nitric acid (%2 V/V) (Merck, Darmstadt, Germany) using a microwave digestion system (Cem Corporation MARS 5 Digestion). The resulting solution was then filtered. A 1 mL aliquot of each filtrate was diluted to 10 mL with ultrapure water. All samples were subsequently placed in the autosampler unit of the ICP-MS instrument (Thermo Scientific™ iCAP™ RQ) for analysis. Calibration solutions were prepared by serial dilutions using ICP-multi element standard solution-IV (1000 mg/L) (Supelco 1.11355.0100, Merck, Darmstadt, Germany). All reagents used were of analytical grade.

Health risks assessment
Salt consumption in Türkiye is twice the levels recommended by the WHO, and considering its sources, each sample needs to be evaluated in terms of Health Risk Assessment (HRA). HRA is a systematic process used to evaluate the potential adverse health effects associated with exposure to environmental, chemical, biological, or physical hazards. This multidisciplinary approach integrates toxicological, epidemiological, and statistical methods to estimate risk levels for individuals or populations.

To assess the health risks of elements in salts, the estimated daily intake (EDI) was calculated using the following formula:
$EDI = (M \times C)/BW$
where M is the daily salt intake (kg/day). C is the elemental concentration (mg/kg) of salts and BW is the body weight (Antoine et al., 2017). Health risks were calculated for 3 age groups: ≥21, 16 to < 21, and 11 to < 16 years.

The reference BWs estimated by The Agency for Toxic Substances and Disease Registry (ATSDR) (2023) were used to evaluate the health risks of these age groups. These values are 80, 71.6, and 56.8 kg, respectively.
Chronic daily intake (CDI) was calculated using the formula:
$CDI = (EDI \times EDtot)/BW$
where EDtot is the exposure duration (years). The Target Hazard Quotient (THQ) indicates the non-carcinogenic health risk caused by exposure to the relevant element (Chebli et al., 2024).

THQ was calculated using the formula:
$THQ = CDI/RfDo$
where RfDo is defined as consumers' daily oral exposure estimate over a long time without experiencing harmful effects and is a specific value for the trace element being assessed. The RfDo values used for Al, B, Cr, Fe, Mn, and Ni are 1, 0.02, 1.5, 0.64, 0.14, and 0.02 mg/kg/day, respectively (Antoine et al., 2017; United States Environmental Protection Agency, 2024). If THQ is <1, non-carcinogenic health effects are not expected. However, if THQ is >1 then there is a possibility that adverse health effects could be experienced.
To evaluate the cumulative risk, the Hazard Index (HI) was calculated by summing the THQ values of each element. If the HI is <1, the risk is acceptable and considered safe for human consumption, but if the HI is >1, consumption should be regarded as a potential health concern (Chebli et al., 2024).

Statistics
Statistical analyses were conducted using the SPSS software (Version 29.0 for Windows, Chicago, Illinois). The normality of continuous variables was evaluated with the Shapiro-Wilk test. For variables with a normal distribution, means and standard deviations were reported, while median values were provided for variables that did not conform to a normal distribution.

Table 1. Information about the analyzed salts in this study

Salt Samples	Type of Salts	Origin Country (Province)
S1	Spring Salt	Türkiye (Kırıkkale)
S2	Spring Salt	Türkiye (Tunceli)
S3	Spring Salt	Türkiye (Sivas)
S4	Himalayan Salt	Pakistan
S5	Himalayan Salt	Pakistan
S6	Himalayan Salt	Pakistan
S7	Rock Salt	Türkiye (Çankırı)
S8	Rock Salt	Türkiye (Yozgat)
S9	Rock Salt	Türkiye (Kars)
S10	Sea Salt	Türkiye (İzmir)
S11	Sea Salt	Türkiye

Results and Discussion

In this study, eleven edible salts commonly consumed in Türkiye were analyzed to determine their essential (calcium, potassium, magnesium, iron, manganese) and non-essential (aluminum, boron, chromium, nickel) element contents. The results showed considerable variation in elemental concentrations among the samples, as summarized in Table 2. The levels of essential and non-essential elements varied significantly among the salts. For instance, calcium concentration ranged from 36.53 mg/kg in S11 to 2,595.26 mg/kg in S5, while iron levels ranged from 1.91 mg/kg in S4 to 39.60 mg/kg in S5.

Table 3 shows the calculated daily intake of essential and non-essential elements level based on the WHO's recommended maximum daily salt intake of 5 g/day and the average daily salt consumption in Türkiye, which is 10.2 g/day. Among the analyzed salts, S5 contributed the highest amounts to the daily intake of calcium, magnesium, potassium, aluminum, boron, iron, manganese, and nickel. Salts S9, S10, and S11 were leading contributors to chromium intake.

The average concentrations indicate that calcium is the most abundant mineral across the samples, with a mean value of 1,046.05 ± 865.2 mg/kg, while manganese is the least abundant, with an average of 0.37 ± 0.37 mg/kg. Notably, sample S5 (a Himalayan salt) contained the highest concentrations of calcium (2,595.26 mg/kg), magnesium (2,457.46 mg/kg), potassium (3,612.00 mg/kg), aluminum (5.60 mg/kg), boron (2.76 mg/kg), iron (39.6 mg/kg), manganese (1.29 mg/kg), and nickel (1.40 mg/kg). Additionally, sample S9 exhibited the highest chromium concentration at 1.07 mg/kg.

Calcium is an essential mineral critical for numerous physiological functions in the body. Sufficient calcium intake is associated with preventing various health conditions, including osteoporosis, colorectal cancer, hypertensive disorders during pregnancy, and reducing LDL cholesterol levels and blood pressure (Cornick and Belizán, 2019). According to the Dietary Guidelines for Türkiye, the tolerable upper intake level (UL) for calcium has been established at 2500 mg/day for individuals aged 19 to 50 (Republic of Turkish Ministry of Health, 2022). In this study, the calcium levels of different types of salt were as follows: Himalayan salt contained 662.26-2595.26 mg/kg, spring salt contained 823.30-1853.27 mg/kg, rock salt contained 340.38-498.24 mg/kg, and sea salt contained 36.53-427.04 mg/kg. The highest calcium level was observed in S5, a Himalayan salt (2595.26 mg/kg). This was followed by S6, another Himalayan salt (2025.00 mg/kg). The lowest calcium level was found in S11, sea salt (36.53 mg/kg). However, in another sea salt, S10, it was 427.04 mg/kg. Himalayan salts are formed through the interaction of underground minerals and sea salt over hundreds of millions of years of geological compression and exposure to high underground temperatures. These ancient geological processes enriched the salts with minerals from the surrounding rocks, resulting in higher concentrations of calcium, magnesium, and potassium (Deng et al., 2023).

A significant proportion of potassium in the body is found within muscles and the skeleton, while the remainder is distributed among the central nervous system, intestines, liver, lungs, and skin. Extracellular potassium plays a crucial role in regulating cell membrane potential, as well as in nerve and muscle activities (D'Elia, 2024). In this study, the highest potassium levels were observed in Himalayan salts (848.63-3612.00 mg/kg), whereas the lowest was found in spring salts (3.30-39.63 mg/kg).

Magnesium is the fourth most abundant cation in the body and is essential for numerous physiological processes. It contributes to blood pressure regulation, myocardial and muscle contraction, neuromuscular transmission, glycemic control, energy production, synthesis of nuclear materials, transmembrane ion transport, and bone development (Al Alawi et al., 2018). In this study, the magnesium levels ranged from 582.88-2457.46 mg/kg in Himalayan salts, 18.57-26.54 mg/kg in spring salts, 33.35-239.02 mg/kg in rock salts, and 89.49-606.22 mg/kg in sea salts.

Aluminum constitutes approximately 8.8% of the Earth's crust by mass and is abundant in many rocks. Its presence in the environment is significantly influenced by natural weathering processes and anthropogenic activities such as coal burning, mining, vehicle exhaust emissions, and waste incineration. These activities contribute extensively to environmental aluminum levels. The adverse health effects of aluminum exposure are primarily linked to neurotoxicity (Alasfar and Isaifan, 2021). Although the precise mechanism remains unclear, elevated aluminum levels have been detected in the brain tissues of patients with Alzheimer's disease and other neurodegenerative disorders (Charlebois and Pantopoulos, 2023). Aluminum exposure has also been associated with lung fibrosis, reduced lung function, bone disorders, kidney damage, hormonal imbalances, and various cancers (Bonfiglio et al., 2023). In this study, the average aluminum concentration in the analyzed salts was 1.23 mg/kg. Himalayan salts exhibited the highest aluminum levels, between 1.03 to 5.60 mg/kg. As shown in Table 3, sample S5 contributed the most to daily aluminum intake (0.057 mg/day). This equates to a weekly aluminum intake of 0.4 mg/week from this salt. According to the European Food Safety Authority (EFSA) (2008), the tolerable weekly aluminum intake for a 70 kg individual is 70 mg/week. None of the salts analyzed in this study exceeded this threshold.

Table 2. The essential and non-essential element content of salt samples (mg/kg) in this study

Salt Samples	Ca	K	Mg	Al	B	Cr	Fe	Mn	Ni
S1	1,853.27	3.30	19.37	0.76	0.06	0.59	23.89	0.48	0.95
S2	1,852.45	6.88	18.57	0.22	0.14	0.67	11.59	0.06	1.00
S3	823.30	3963	26.54	0.23	0.85	0.55	5.26	0.11	0.46
S4	662.26	949.68	1,443.65	2.61	0.91	0.76	11.91	0.53	0.43
S5	2,595.26	3,612.00	2,457.46	5.60	2.76	0.50	39.60	1.29	1.40
S6	2,025.60	848.63	582.88	1.03	0.37	0.64	31.32	0.30	1.12
S7	498.24	51.96	33.35	0.13	0.15	0.70	6.43	0.06	0.32
S8	340.38	67.20	239.02	0.56	1.39	0.63	5.46	0.19	0.26
S9	392.17	105.78	205.75	0.89	0.90	1.07	7.99	0.13	0.29
S10	427.04	184.88	606.22	0.51	3.80	1.04	6.68	0.17	0.40
S11	36.53	65.13	89.49	1.01	0.27	1.05	2.56	0.72	0.61
Mean (Median)	1,046.05	539.55 (67.20)	520.21 (205.75)	1.23 (0.76) 1.60	1.05 (0.85)	0.75 (0.67) 0.21	13.88 (799)	0.37 (0.19) 0.37	0.66
SD	865.2	1,074	772.3		1.20		12.21		0.39

SD: Standard deviation. Median values are given in parentheses for non-parametric variables.

Table 3. Daily essential and non-essential elements intake (mg/day) from salt

	Ca		K		Mg		Al		B	
Salt No	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**
S1	9.266	18.903	0.017	0.034	0.097	0.198	0.004	0.008	0.000	0.001
S2	9.262	18.895	0.034	0.070	0.093	0.189	0.001	0.002	0.001	0.001
S3	4.117	8.398	0.198	0.404	0.133	0.271	0.001	0.002	0.004	0.009
S4	3.311	6.755	4.748	9.687	7.218	14.725	0.013	0.027	0.005	0.009
S5	12.976	26.472	18.060	36.842	12.287	25.066	0.028	0.057	0.014	0.028
S6	10.128	20.661	4.243	8.656	2.914	5.945	0.005	0.011	0.002	0.004
S7	2.491	5.082	0.260	0.530	0.167	0.340	0.001	0.001	0.001	0.002
S8	1.702	3.472	0.336	0.685	1.195	2.438	0.003	0.006	0.007	0.014
S9	1.961	4.000	0.529	1079	1.029	2.099	0.005	0.009	0.005	0.009
S10	2.135	4.356	0.924	1.886	3.031	6.183	0.003	0.005	0.019	0.039
S11	0.183	0.373	0.326	0.664	0.448	0.913	0.005	0.010	0.001	0.003

	Cr		Fe		Mn		Ni	
Salt No	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**	**WHO**	**THNS**
S1	0.003	0.006	0.120	0.244	0.002	0.005	0.005	0.010
S2	0.003	0.007	0.058	0.118	0.000	0.001	0.005	0.010
S3	0.003	0.006	0.026	0.054	0.001	0.001	0.002	0.005
S4	0.004	0.008	0.060	0.122	0.003	0.005	0.002	0.004
S5	0.003	0.005	0.198	0.404	0.006	0.013	0.007	0.014
S6	0.003	0.007	0.157	0.320	0.002	0.003	0.006	0.011
S7	0.004	0.007	0.032	0.066	0.000	0.001	0.002	0.003
S8	0.003	0.006	0.027	0.056	0.001	0.002	0.001	0.003
S9	0.005	0.011	0.040	0.082	0.001	0.001	0.002	0.003
S10	0.005	0.011	0.033	0.068	0.001	0.002	0.002	0.004
S11	0.005	0.011	0.013	0.026	0.004	0.007	0.003	0.006

WHO: World Health Organization's maximum daily salt intake recommendation (5 g), THNS: Average daily salt intake for people aged 15 and over in Türkiye (10.2 g).

Boron, which has been shown to positively affect human health in recent years, is regarded as a potentially essential element (Sosa-Baldivia et al., 2016). The average daily intake of boron through diet and drinking water is approximately 1.85 mg/day (Kuru et al., 2018; Kuru et al., 2020). The United States Committee on Medicines, Food, and Nutrition (2001) has established the tolerable upper intake level (UL) for boron at 20 mg/day for adults, while the EFSA (2023) has set this value at 10 mg/day. Consuming boron in excess of 500 mg/day can result in toxicity symptoms, including headache, abdominal pain, nausea, vomiting, diarrhea, muscle contractions, weakness, disorders of the digestive and central nervous systems, glandular dysfunction, skin lesions, and shock. In this study, boron levels in different types of salt were found as follows: 0.06-0.85 mg/kg in spring salts, 0.37-2.76 mg/kg in Himalayan salts, 0.15-1.39 mg/kg in rock salts and 0.27-3.80 mg/kg in sea salts. The sample S10 contributed the highest amount to daily boron intake (0.039 mg/day). These findings indicate that it is not possible to exceed the established UL for boron through the consumption of the salts analyzed in this study.

Chromium is a potentially toxic metal released into water and groundwater from both natural and anthropogenic sources. Exposure to chromium poses serious health risks, affecting the skin, eyes, blood, respiratory and immune systems. At the cellular level, chromium exhibits genotoxic properties that can induce oxidative stress, and DNA damage, which can contribute to tumor formation (Tumolo et al., 2020). EFSA has found no convincing evidence that chromium is an essential element. One of the significant challenges in evaluating chromium deficiency is the absence of a recognized biomarker to assess chromium nutritional status (EFSA, 2014). Consequently, neither the UL nor the adequate intake level of chromium has been established. In this study, the highest chromium concentration was found in S9 (1.07 mg/kg), a rock salt, followed by S10 and S11 (1.04 and 1.05 mg/kg), sea salts with very close concentrations.

Iron is a crucial nutrient essential for oxygen transport and cellular respiration. Iron deficiency anemia remains a significant global health challenge, particularly affecting vulnerable populations such as indigenous communities, refugees, immigrants from low- and middle-income countries, and other disadvantaged groups. However, excessive iron levels in the body can lead to adverse health outcomes, primarily due to increased oxidative stress and resultant tissue damage (Vincent and Lukaski, 2018). In another study, the iron content in Himalayan salt was determined as 0.299 ± 0.0323 mg/kg using the ICP-MS method (Ercoşkun, 2022). In the present study, the iron levels ranged from 5.26 to 23.89 mg/kg in spring salt, 11.91 to 39.60 mg/kg in Himalayan salt, 5.46 to 7.99 mg/kg in rock salt, and 2.56 to 6.68 mg/kg in sea salt. The highest iron levels were observed in S5 (39.60 mg/kg), a Himalayan salt, followed by S6 (31.32 mg/kg), another Himalayan salt. The tolerable UL for iron is 45 mg/day (Republic of Turkish Ministry of Health, 2022). Based on the findings of this study, it is not possible to exceed this UL through the consumption of the analyzed salts.

Manganese is an essential trace element involved in the synthesis and activation of various enzymes in humans, as well as the regulation of glucose and lipid metabolism. Additionally, manganese is a critical component of manganese superoxide dismutase, an enzyme primarily responsible for scavenging reactive oxygen species during mitochondrial oxidative stress. Both manganese deficiency and toxicity have been linked to adverse metabolic and neuropsychiatric effects (Li and Yang, 2018). In this study, manganese levels ranged between 0.06-0.48 mg/kg in spring salt, 0.30-1.29 mg/kg in Himalayan salt, 0.06-0.19 mg/kg in rock salt, and 0.17-0.72 mg/kg in sea salt. The highest manganese level was in S5 (1.29 mg/kg), a Himalayan salt. The tolerable upper intake level (UL) for manganese is 11 mg/day (Republic of Turkish Ministry of Health, 2022). As shown in Table 3, it is unlikely that the examined salts would lead to manganese intake exceeding this threshold.

Nickel is a transition metal widely distributed in the environment, including air, water, and soil. Human exposure to nickel occurs through dietary sources, water, and inhalation. Nickel is present in fertilizers, vehicle exhaust, cigarettes, pesticides, industrial waste, and everyday materials such as jewelry, utensils, keys, and coins. Nickel exposure has been associated with allergic contact dermatitis, systemic contact dermatitis, and Systemic Nickel Allergy Syndrome (Conti et al., 2021). Although the precise molecular mechanisms remain unclear, the nervous system is one of the primary targets for nickel toxicity (Genchi et al., 2020). Recent studies have focused on nickel's role in enzymatic functions, its beneficial effects on nitrogen utilization in plants, its mechanisms of allergy induction, and its presence in food and biological tissues (Nielsen, 2021). The UL for nickel is 1.0 mg/day as soluble salts for individuals aged ≥14 years (ATSDR, 2024). Based on Table 3, it appears that the nickel content in the examined salts would not lead to intakes exceeding this UL. In this study, the lowest nickel levels were in S8, a rock salt (0.26 mg/kg), and the highest in S5 and S6, Himalayan salts (1.40 and 1.12 mg/kg). However, these Himalayan salts may not be suitable for individuals with allergic contact dermatitis, systemic contact dermatitis, or Systemic Nickel Allergy Syndrome.

Di Salvo et al. (2023) analyzed the calcium, aluminum, iron, chromium, manganese, and nickel content of 10 commercial gourmet table salts in Southern Italy using the ICP-MS method, reporting values of 3,129.34, 4.82, 5.31, 0.56, 2.17, and 2.71 mg/kg, respectively. In comparison, the values we obtained were 1,046.05, 1.23, 13.88, 0.75, 0.37, and 0.66 mg/kg, respectively, which are generally lower than those reported by Di Salvo et al (2023). Specifically, for Himalayan pink salt, their reported concentrations of calcium, aluminum, iron, chromium, manganese, and nickel were 2,926, 4.4, 2.6, 0.9, 0.0074, and 1.3 mg/kg, respectively, whereas our study found values of between 662.26-2595.26, 1.03-5.60, 11.91-29.60, 0.50-0.76, 0.30-1.29, and 0.43-1.40 mg/kg. While chromium levels in their study were higher, our iron and manganase concentrations were significantly greater. These discrepancies may be attributed to differences in the salt source, mineralogy, salt type, geographical origin, geological features, or industrial activities surrounding the salt sources.

Table 4 presents the EDI and CDI levels of essential and non-essential elements from salts across all analyzed age groups, showing that these values remain below the RFD thresholds. Additionally, all THQ and HI levels are below 1, indicating no significant non-carcinogenic health risks associated with salt consumption in these age groups.

A study conducted in Pakistan found that salts obtained from the Sandpit salt fields, which receive untreated wastewater via the Lyari River, exhibited THQ values that were 2 to 6 times higher than the reference values, while HI values exceeded the acceptable threshold by of 20 times in terms of heavy metal contamination (Chan et al., 2021). Given the variability in salt sources and the potential health risks associated with elements, THQ and HI levels were conducted for the samples included in this study. The results indicate that aluminum, boron, chromium, iron, manganese, and nickel were present in varying concentrations across the analyzed salt samples. Notably, Himalayan salts contained the highest levels of aluminum (up to 5.60 mg/kg), iron (up to 39.60 mg/kg), and manganese (up to 1.29 mg/kg). However, despite these concentrations, HRA calculations demonstrated that the EDI and CDI of heavy metals remained below the reference dose (RfD) values for all age groups.

Table 5 provides the percentage contribution of each salt's consumption in our study to the daily dietary reference values, calculated based on the average daily salt intake in Türkiye (10.2 mg/day). These calculations were conducted using the Dietary Guideline for Türkiye (Republic of Türkiye Ministry of Health, 2022), the Summary Report on Nutrition Reference Values for Foods of the EFSA (2017), and the Food and Nutrition Board's Dietary Reference Intakes Review Committee (2019). The highest contributions to daily intake were observed for magnesium, calcium, and iron. S5, a Himalayan salt, provided the largest contribution to the Recommended Dietary Allowance (RDA) of calcium, potassium, magnesium, iron, and manganese. The contribution of S5 to the RDA of calcium in females and males ranged between 2.65-2.79%. In comparison, S11, a sea salt, contributed only 0.04% to the RDA of calcium. For potassium, S5 contributed between 0.78% and 1.42% in females, while males in 0.78% to 1.08%. Salts S1 and S2 had almost negligible contributions to daily potassium intake. The contribution of S5 to the RDA of magnesium was between 8.09-8.36% in females and 5.97-7.16% in males. In contrast, S2 only contributed 0.06% in females and 0.05% in males. The contribution of S5 to the RDA of iron was 2.24-2.52% in females and 3.67-5.05% in males. Regarding iron, S5's contribution to the RDA was between 2.24% and 2.52% in females and between 3.67% and 5.05% in males. In comparison, S11's contribution was almost one-fifteenth of S5's. Although the contributions of salts to the daily RDA are different, it is seen that salt consumption contributes minimally to overall daily nutritional requirements.

This study provides valuable insights into the essential and non-essential elements content of table salts commonly consumed in Türkiye. While Himalayan salts exhibited higher concentrations of essential elements, their contribution to daily nutritional intake remains limited. Importantly, the HRA confirmed that the determined element levels in the analyzed salts do not pose significant non-carcinogenic risks. However, continued monitoring and regulation of salt sources are essential to ensure consumer safety. Future research should focus on the potential interactions between essential and non-essential elements in food products and their cumulative health effects over time.

Consequently, in this study, the essential and non-essential elements levels in 11 salt samples frequently consumed in Türkiye were found to comply with the Dietary Reference Intake Levels and Codex Limits. While no adverse health risks were identified based on the HRA in terms of analysed elements it remains crucial to perform thorough element analyses before these salts are made available for consumption to ensure public health safety. Although the examined salts contained varying amounts of elements, their contribution to meeting daily adequate intake levels appears to be minimal.

Table 4. EDI, CDI, THQ, and HI levels of elements from salt across different age groups

Salts	Element	Estimated Daily Intake			Chronic Daily Intake			Target Hazard Quotient			Hazard Index		
		Age (years)			Age (years)			Age (years)			Age (years)		
		≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16	≥21	16 to <21	11 to <16
S1	Al	9.70^{E-05}	1.08^{E-04}	1.36^{E-04}	8.48^{E-05}	1.06^{E-04}	1.68^{E-04}	8.48^{E-05}	1.06^{E-04}	6.64^{E-04}	0.01	0.01	0.02
	B	7.70^{E-06}	8.55^{E-06}	1.08^{E-05}	6.69^{E-06}	8.36^{E-06}	1.33^{E-05}	3.35^{E-04}	4.18^{E-04}	1.68^{E-04}			
	Cr	7.50^{E-05}	8.41^{E-05}	1.06^{E-04}	6.58^{E-05}	8.22^{E-05}	1.31^{E-04}	4.39^{E-05}	5.48^{E-05}	8.70^{E-05}			
	Fe	3.00^{E-03}	3.40^{E-03}	4.29^{E-03}	2.67^{E-03}	3.33^{E-03}	5.29^{E-03}	4.16^{E-03}	5.20^{E-03}	8.26^{E-03}			
	Mn	6.10^{E-05}	6.84^{E-05}	8.62^{E-05}	5.36^{E-05}	6.69^{E-05}	1.06^{E-04}	3.83^{E-04}	4.78^{E-04}	7.59^{E-04}			
	Ni	1.20^{E-04}	1.35^{E-04}	1.71^{E-04}	1.06^{E-04}	1.32^{E-04}	2.10^{E-04}	5.30^{E-03}	6.62^{E-03}	1.05^{E-02}			
S2	Al	2.80^{E-05}	3.13^{E-05}	3.95^{E-05}	2.45^{E-05}	3.06^{E-05}	4.87^{E-05}	2.45^{E-05}	3.06^{E-05}	1.55^{E-03}	0.01	0.01	0.02
	B	1.80^{E-05}	1.99^{E-05}	2.51^{E-05}	1.56^{E-05}	1.95^{E-05}	3.10^{E-05}	7.81^{E-04}	9.75^{E-04}	4.87^{E-05}			
	Cr	8.50^{E-05}	9.54^{E-05}	1.20^{E-04}	7.47^{E-05}	9.33^{E-05}	1.48^{E-04}	4.98^{E-05}	6.22^{E-05}	9.89^{E-05}			
	Fe	1.50^{E-03}	1.65^{E-03}	2.08^{E-03}	1.29^{E-03}	1.61^{E-03}	2.56^{E-03}	2.02^{E-03}	2.52^{E-03}	4.01^{E-03}			
	Mn	7.80^{E-06}	8.69^{E-06}	1.10^{E-05}	6.81^{E-06}	8.50^{E-06}	1.35^{E-05}	4.86^{E-05}	6.07^{E-05}	9.64^{E-05}			
	Ni	1.30^{E-04}	1.42^{E-04}	1.80^{E-04}	1.12^{E-04}	1.39^{E-04}	2.21^{E-04}	5.58^{E-03}	6.96^{E-03}	1.11^{E-02}			
S3	Al	2.90^{E-05}	3.28^{E-05}	4.13^{E-05}	2.57^{E-05}	3.20^{E-05}	5.09^{E-05}	2.57^{E-05}	3.20^{E-05}	9.41^{E-03}	0.01	0.01	0.02

	B	1.10^{E-04}	1.21^{E-04}	1.53^{E-04}	9.48^{E-05}	1.18^{E-04}	1.88^{E-04}	4.74^{E-03}	5.92^{E-03}	5.09^{E-05}			
	Cr	7.00^{E-05}	7.84^{E-05}	9.88^{E-05}	6.14^{E-05}	7.66^{E-05}	1.22^{E-04}	4.09^{E-05}	5.11^{E-05}	8.11^{E-05}			
	Fe	6.70^{E-04}	7.49^{E-04}	9.45^{E-04}	5.87^{E-04}	7.33^{E-04}	1.16^{E-03}	9.17^{E-04}	1.14^{E-03}	1.82^{E-03}			
	Mn	1.40^{E-05}	1.51^{E-05}	1.90^{E-05}	1.18^{E-05}	1.48^{E-05}	2.35^{E-05}	8.45^{E-05}	1.05^{E-04}	1.68^{E-04}			
	Ni	5.90^{E-05}	6.55^{E-05}	8.26^{E-05}	5.13^{E-05}	6.41^{E-05}	1.02^{E-04}	2.57^{E-03}	3.20^{E-03}	5.09^{E-03}			
S4	Al	3.30^{E-04}	3.72^{E-04}	4.69^{E-04}	2.91^{E-04}	3.64^{E-04}	5.78^{E-04}	2.91^{E-04}	3.64^{E-04}	1.01^{E-02}	0.01	0.01	0.02
	B	1.20^{E-04}	1.30^{E-04}	1.63^{E-04}	1.02^{E-04}	1.27^{E-04}	2.01^{E-04}	5.08^{E-03}	6.34^{E-03}	5.78^{E-04}			
	Cr	9.70^{E-05}	1.08^{E-04}	1.36^{E-04}	8.48^{E-05}	1.06^{E-04}	1.68^{E-04}	5.65^{E-05}	7.06^{E-05}	1.12^{E-04}			
	Fe	1.50^{E-03}	1.70^{E-03}	2.14^{E-03}	1.33^{E-03}	1.66^{E-03}	2.64^{E-03}	2.08^{E-03}	2.59^{E-03}	4.12^{E-03}			
	Mn	6.80^{E-05}	7.59^{E-05}	9.57^{E-05}	5.95^{E-05}	7.42^{E-05}	1.18^{E-04}	4.25^{E-04}	5.30^{E-04}	8.43^{E-04}			
	Ni	5.50^{E-05}	6.13^{E-05}	7.72^{E-05}	4.80^{E-05}	5.99^{E-05}	9.52^{E-05}	2.40^{E-03}	2.99^{E-03}	4.76^{E-03}			
S5	Al	7.10^{E-04}	7.98^{E-04}	1.01^{E-03}	6.25^{E-04}	7.80^{E-04}	1.24^{E-03}	6.25^{E-04}	7.80^{E-04}	3.05^{E-02}	0.03	0.04	0.06
	B	3.50^{E-04}	3.93^{E-04}	4.96^{E-04}	3.08^{E-04}	3.84^{E-04}	6.11^{E-04}	1.54^{E-02}	1.92^{E-02}	1.24^{E-03}			
	Cr	6.40^{E-05}	7.12^{E-05}	8.98^{E-05}	5.58^{E-05}	6.96^{E-05}	1.11^{E-04}	3.72^{E-05}	4.64^{E-05}	7.38^{E-05}			
	Fe	5.00^{E-03}	5.64^{E-03}	7.11^{E-03}	4.42^{E-03}	5.52^{E-03}	8.76^{E-03}	6.90^{E-03}	8.62^{E-03}	1.37^{E-02}			
	Mn	1.60^{E-04}	1.83^{E-04}	2.31^{E-04}	1.44^{E-04}	1.79^{E-04}	2.85^{E-04}	1.03^{E-03}	1.28^{E-03}	2.03^{E-03}			
	Ni	1.80^{E-04}	1.99^{E-04}	2.51^{E-04}	1.56^{E-04}	1.95^{E-04}	3.10^{E-04}	7.80^{E-03}	9.74^{E-03}	1.55^{E-02}			
S6	Al	1.30^{E-04}	1.47^{E-04}	1.85^{E-04}	1.15^{E-04}	1.43^{E-04}	2.28^{E-04}	1.15^{E-04}	1.43^{E-04}	4.09^{E-03}	0.01	0.02	0.03
	B	4.70^{E-05}	5.27^{E-05}	6.64^{E-05}	4.13^{E-05}	5.15^{E-05}	8.19^{E-05}	2.06^{E-03}	2.58^{E-03}	2.28^{E-04}			
	Cr	8.20^{E-05}	9.12^{E-05}	1.15^{E-04}	7.14^{E-05}	8.91^{E-05}	1.42^{E-04}	4.76^{E-05}	5.94^{E-05}	9.44^{E-05}			
	Fe	4.00^{E-03}	4.46^{E-03}	5.62^{E-03}	3.49^{E-03}	4.36^{E-03}	6.93^{E-03}	5.46^{E-03}	6.82^{E-03}	1.08^{E-02}			
	Mn	3.80^{E-05}	4.25^{E-05}	5.35^{E-05}	3.32^{E-05}	4.15^{E-05}	6.60^{E-05}	2.37^{E-04}	2.96^{E-04}	4.71^{E-04}			
	Ni	1.40^{E-04}	1.60^{E-04}	2.01^{E-04}	1.25^{E-04}	1.56^{E-04}	2.48^{E-04}	6.25^{E-03}	7.80^{E-03}	1.24^{E-02}			
S7	Al	1.70^{E-05}	1.85^{E-05}	2.33^{E-05}	1.45^{E-05}	1.81^{E-05}	2.88^{E-05}	1.45^{E-05}	1.81^{E-05}	1.60^{E-03}	0.00	0.00	0.01
	B	1.80^{E-05}	2.07^{E-05}	2.60^{E-05}	1.62^{E-05}	2.02^{E-05}	3.21^{E-05}	8.09^{E-04}	1.01^{E-03}	2.88^{E-05}			
	Cr	8.90^{E-05}	9.97^{E-05}	1.26^{E-04}	7.81^{E-05}	9.75^{E-05}	1.55^{E-04}	5.21^{E-05}	6.50^{E-05}	1.03^{E-04}			
	Fe	8.20^{E-04}	9.16^{E-04}	1.15^{E-03}	7.17^{E-04}	8.96^{E-04}	1.42^{E-03}	1.12^{E-03}	1.40^{E-03}	$2..22^{E-03}$			
	Mn	7.90^{E-06}	8.83^{E-06}	1.11^{E-05}	6.92^{E-06}	8.64^{E-06}	1.37^{E-05}	4.94^{E-05}	6.17^{E-05}	9.80^{E-05}			
	Ni	4.10^{E-05}	4.56^{E-05}	5.75^{E-05}	3.57^{E-05}	4.46^{E-05}	7.08^{E-05}	1.79^{E-03}	2.23^{E-03}	3.54^{E-03}			
S8	Al	1.30^{E-04}	7.98^{E-05}	1.01^{E-04}	6.25^{E-05}	7.80^{E-05}	1.24^{E-04}	6.25^{E-05}	7.80^{E-05}	1.54^{E-02}	0.01	0.01	0.02
	B	3.40^{E-05}	1.98^{E-04}	2.50^{E-04}	1.55^{E-04}	1.94^{E-04}	3.08^{E-04}	7.75^{E-03}	9.68^{E-03}	1.24^{E-04}			
	Cr	1.30^{E-04}	8.97^{E-05}	1.13^{E-04}	7.03^{E-05}	8.77^{E-05}	1.39^{E-04}	4.69^{E-05}	5.85^{E-05}	9.30^{E-05}			
	Fe	3.30^{E-04}	7.78^{E-04}	9.80^{E-04}	6.09^{E-04}	7.60^{E-04}	1.21^{E-03}	9.52^{E-04}	1.19^{E-03}	1.89^{E-03}			
	Mn	9.20^{E-05}	2.76^{E-05}	3.48^{E-05}	2.16^{E-05}	2.70^{E-05}	4.29^{E-05}	1.55^{E-04}	1.93^{E-04}	3.07^{E-04}			
	Ni	7.80^{E-05}	3.70^{E-05}	4.67^{E-05}	2.90^{E-05}	3.62^{E-05}	5.75^{E-05}	1.45^{E-03}	1.81^{E-03}	2.88^{E-03}			
S9	Al	9.70^{E-05}	1.27^{E-04}	1.60^{E-04}	9.93^{E-05}	1.24^{E-04}	1.97^{E-04}	9.93^{E-05}	1.24^{E-04}	9.96^{E-03}	0.01	0.01	0.02
	B	7.70^{E-06}	1.28^{E-04}	1.62^{E-04}	1.00^{E-04}	1.25^{E-04}	1.99^{E-04}	5.02^{E-03}	6.27^{E-03}	1.97^{E-04}			
	Cr	7.50^{E-05}	1.52^{E-04}	1.92^{E-04}	1.19^{E-04}	1.49^{E-04}	2.37^{E-04}	7.96^{E-05}	9.93^{E-05}	1.58^{E-04}			
	Fe	3.00^{E-03}	1.14^{E-03}	1.43^{E-03}	8.91^{E-04}	1.11^{E-03}	1.77^{E-03}	1.39^{E-03}	1.74^{E-03}	2.76^{E-03}			
	Mn	6.10^{E-05}	1.85^{E-05}	2.33^{E-05}	1.45^{E-05}	1.81^{E-05}	2.88^{E-05}	1.04^{E-04}	1.29^{E-04}	2.06^{E-04}			
	Ni	1.20^{E-04}	4.13^{E-05}	5.21^{E-05}	3.24^{E-05}	4.04^{E-05}	6.42^{E-05}	1.62^{E-03}	2.02^{E-03}	3.21^{E-03}			
S10	Al	2.80^{E-05}	7.27^{E-05}	9.16^{E-05}	5.69^{E-05}	7.10^{E-05}	1.13^{E-04}	5.69^{E-05}	7.10^{E-05}	4.20^{E-02}	0.03	0.03	0.05
	B	1.80^{E-05}	5.41^{E-04}	6.82^{E-04}	4.24^{E-04}	5.29^{E-04}	8.41^{E-04}	2.12^{E-02}	2.65^{E-02}	1.13^{E-04}			
	Cr	8.50^{E-05}	1.48^{E-04}	1.87^{E-04}	1.16^{E-04}	1.45^{E-04}	2.30^{E-04}	7.74^{E-05}	9.66^{E-05}	1.53^{E-04}			
	Fe	1.50^{E-03}	9.52^{E-04}	1.20^{E-03}	7.45^{E-04}	9.30^{E-04}	1.48^{E-03}	1.16^{E-03}	1.45^{E-03}	2.31^{E-03}			
	Mn	7.80^{E-06}	2.42^{E-05}	3.05^{E-05}	1.90^{E-05}	2.37^{E-05}	3.76^{E-05}	1.35^{E-04}	1.69^{E-04}	2.69^{E-04}			
	Ni	1.30^{E-04}	5.70^{E-05}	7.18^{E-05}	4.46^{E-05}	5.57^{E-05}	8.85^{E-05}	2.23^{E-03}	2.79^{E-03}	4.43^{E-03}			
S11	Al	2.90^{E-05}	1.44^{E-04}	1.81^{E-04}	1.13^{E-04}	1.41^{E-04}	2.24^{E-04}	1.13^{E-04}	1.41^{E-04}	2.99^{E-03}	0.01	0.01	0.01
	B	1.10^{E-04}	3.85^{E-05}	4.85^{E-05}	3.01^{E-05}	3.76^{E-05}	5.98^{E-05}	1.51^{E-03}	1.88^{E-03}	2.24^{E-04}			
	Cr	7.00^{E-05}	1.50^{E-04}	1.89^{E-04}	1.17^{E-04}	1.46^{E-04}	2.32^{E-04}	7.81^{E-05}	9.75^{E-05}	1.55^{E-04}			
	Fe	6.70^{E-04}	3.65^{E-04}	4.60^{E-04}	2.86^{E-04}	3.57^{E-04}	5.67^{E-04}	4.46^{E-04}	5.57^{E-04}	8.85^{E-04}			
	Mn	1.40^{E-05}	1.03^{E-04}	1.29^{E-04}	8.03^{E-05}	1.00^{E-04}	1.59^{E-04}	5.74^{E-04}	7.16^{E-04}	1.14^{E-03}			
	Ni	5.90^{E-05}	8.69^{E-05}	1.10^{E-04}	6.81^{E-05}	8.50^{E-05}	1.35^{E-04}	3.40^{E-03}	4.25^{E-03}	6.75^{E-03}			

Table 5. Percentages of daily dietary reference values met by the salts analyzed in this study

Contribution of salts to dietary reference values (%)							
		Female			Male		
	Salts	a	b	c	a	b	c
Ca	S1	1.99	1.89	1.89	1.99	1.89	1.89
	S2	1.99	1.89	1.89	1.99	1.89	1.89
	S3	0.88	0.84	0.84	0.88	0.84	0.84
	S4	0.71	0.68	0.68	0.71	0.68	0.68
	S5	2.79	2.65	2.65	2.79	2.65	2.65
	S6	2.17	2.07	2.07	2.17	2.07	2.07
	S7	0.53	0.51	0.51	0.53	0.51	0.51
	S8	0.37	0.35	0.35	0.37	0.35	0.35
	S9	0.42	0.40	0.40	0.42	0.40	0.40
	S10	0.46	0.44	0.44	0.46	0.44	0.44
	S11	0.04	0.04	0.04	0.04	0.04	0.04
K	S1	0.00	0.00	0.00	0.00	0.00	0.00
	S2	0.00	0.00	0.00	0.00	0.00	0.00

	S3	0.01	0.01	0.02	0.01	0.01	0.01
	S4	0.28	0.21	0.37	0.28	0.21	0.28
	S5	1.05	0.78	1.42	1.05	0.78	1.08
	S6	0.25	0.18	0.33	0.25	0.18	0.25
	S7	0.02	0.01	0.02	0.02	0.01	0.02
	S8	0.02	0.01	0.03	0.02	0.01	0.02
	S9	0.03	0.02	0.04	0.03	0.02	0.03
	S10	0.05	0.04	0.07	0.05	0.04	0.06
	S11	0.02	0.01	0.03	0.02	0.01	0.02
Mg	S1	0.07	0.07	0.06	0.05	0.06	0.05
	S2	0.06	0.06	0.06	0.05	0.05	0.05
	S3	0.09	009	0.09	0.08	0.08	0.06
	S4	4.91	4.91	4.75	4.09	4.21	3.51
	S5	8.36	8.36	8.09	6.96	7.16	5.97
	S6	1.98	1.98	1.92	1.65	1.70	1.42
	S7	0.11	0.11	0.11	0.09	0.10	0.08
	S8	0.81	0.81	0.79	0.68	0.70	0.58
	S9	0.70	0.70	0.68	0.58	0.60	0.50
	S10	2.06	2.06	1.99	1.72	1.77	1.47
	S11	0.30	0.30	0.29	0.25	0.26	0.22
Fe	S1	1.52	1.52	1.35	2.22	2.22	3.05
	S2	0.74	0.74	0.66	1.07	1.07	1.48
	S3	0.34	0.34	0.30	0.49	0.49	0.67
	S4	0.76	0.76	0.67	1.10	1.10	1.52
	S5	2.52	2.52	2.24	3.67	3.67	5.05
	S6	2.00	2.00	1.77	2.90	2.90	3.99
	S7	0.41	0.41	0.36	0.60	0.60	0.82
	S8	0.35	0.35	0.31	0.51	0.51	0.70
	S9	0.51	0.51	0.45	0.74	0.74	1.02
	S10	0.43	0.43	0.38	0.62	0.62	0.85
	S11	0.16	0.16	0.15	0.24	0.24	0.33
Mn	S1	0.16	0.16	0.27	0.16	0.16	0.21
	S2	0.02	0.02	0.03	0.02	0.02	0.03
	S3	0.04	0.04	0.06	0.04	0.04	0.05
	S4	0.18	0.18	0.30	0.18	0.18	0.24
	S5	0.44	0.44	0.73	0.44	0.44	0.57
	S6	0.10	0.10	0.17	0.10	0.10	0.13
	S7	0.02	0.02	0.04	0.02	0.02	0.03
	S8	0.07	0.07	0.11	0.07	0.07	0.09
	S9	0.04	0.04	0.07	0.04	0.04	0.06
	S10	0.06	0.06	0.10	0.06	0.06	0.08
	S11	0.24	0.24	0.41	0.24	0.24	0.32

Values are given in %. a: EFSA (2017) (Population reference intakes and adequate intakes for minerals, for ≥18 years). b: Republic of Türkiye Ministry of Health-Dietary Guideline for Türkiye (2022) (Population reference intakes and adequate intakes for minerals, for 18-70 years), c: Food and Nutrition Board (2019) Recommended dietary allowances and adequate intakes, elements, for 19-50 years).

Acknowledgements: None.

References

Al Alawi AM, Majoni SW, Falhammar H. 2018. Magnesium and human health: Perspectives and research directions. International Journal of Endocrinology, 2018: 9041694. doi: 10.1155/2018/9041694

Alasfar RH, Isaifan RJ. 2021. Aluminum environmental pollution: The silent killer. Environmental Science and Pollution Research International, 28(33): 44587-44597. doi: 10.1007/s11356-021-14700-0

Ali H, Khan E, Ilahi I. 2019. Environmental chemistry and ecotoxicology of hazardous heavy metals: Environmental persistence, toxicity, and bioaccumulation. Journal of Chemistry, 2019: 6730305. doi: 10.1155/2019/6730305

Antoine JMR, Fung LAH, Grant CN. 2017. Assessment of the potential health risks associated with the aluminum, arsenic, cadmium and lead content in selected fruits and vegetables grown in Jamaica. Toxicology Reports, 4: 181-187. doi: 10.1016/j.toxrep.2017.03.006

ATSDR. 2023. Agency for Toxic Substances and Disease Registry. Exposure dose guidance for body weight. Available from: https://www.atsdr.cdc.gov/pha-guidance/resources/ATSDR-EDG-Body-Weight-508.pdf [Accessed 28 March 2025]

ATSDR. 2024. Agency for Toxic Substances and Disease Registry. Toxicological profile for nickel. Available from: https://wwwn.cdc.gov/TSP/ToxProfiles/ToxProfiles.aspx?id=245&tid=44 [Accessed 28 March 2025].

Bonfiglio R, Scimeca M, Mauriello A. 2023. The impact of aluminum exposure on human health. Archives of Toxicology, 97: 2997-2998. doi: 10.1007/s00204-023-03581-6

Chan MWH, Hasan KA, Balthazar-Silva D, Mirani ZA, Asghar M. 2021. Evaluation of heavy metal pollutants in salt and seawater under the influence of the Lyari River and potential health risk assessment. Marine Pollution Bulletin, 166: 112215. doi: 10.1016/j.marpolbul.2021.112215

Charlebois E, Pantopoulos K. 2023. Nutritional aspects of iron in health and disease. Nutrients, 15: 2441. doi: 10.3390/nu15112441

Chebli AI, Zergui A, Amziane A, Zebbiche Y, Abdennour S. 2024. Metals in honey, cow's milk and eggs in North-East Algeria and health risk. Food Additives & Contaminants: Part B, 16: 1-10. doi: 10.1080/19393210.2024.2414088

Conti MV, Bissacco G, De Giuseppe R, Calcagno MG, D'Antona G, Cena H. 2021. Systemic nickel allergy syndrome (SNAS): Taking stock of medical nutrition therapy SNAS and nutrition. Journal of Community Medicine and Public Health Reports, 5: 225. doi: 10.29011/2577-2228.100225

Cormick G, Belizán JM. 2019. Calcium intake and health. Nutrients, 11: 1606. doi: 10.3390/nu11071606

D'Elia L. 2024. Potassium intake and human health. Nutrients, 16: 833. doi: 10.3390/nu16060833

Demir F, Kipcak AS, Dere Ozdemir O, Moroydor Derun E. 2020. Determination of essential and non-essential element concentrations and health risk assessment of some commercial fruit juices in Turkey. Journal of Food Science and Technology, 57: 4432-4442. doi: 10.1007/s13197-020-04480-9

Deng Z, Huang X, Wei C, Zhang Y, Wang L. 2023. Characteristics and purification of Himalayan salt by high temperature melting. High Temperature Materials and Processes, 42: 20220274. doi: 10.1515/htmp-2022-0274

Di Salvo E, Tardugno R, Nava V, D'Agostino A, Marrocco MRG. 2023. Gourmet table salts: The mineral composition showdown. Toxics, 11: 705. doi: 10.3390/toxics11080705

Elias M, Laranjo M, Agulheiro-Santos AC, Potes ME. The role of salt on food and human health. In: Çinku M, editor. Salt in the Earth. London: IntechOpen. 2020. https://doi.org/10.5772/intechopen.86905

Ercoşkun H. 2022. Impurities of natural salts of the earth. Food Additives & Contaminants: Part B, 16: 24-31. doi: 10.1080/19393210.2022.2114016

Erdem Y, Akpolat T, Derici Ü, Şengül Ş, Ertürk Ş, Ulusoy Ş. 2017. Dietary sources of high sodium intake in Turkey: SALTURK II. Nutrients, 9: 933. doi: 10.3390/nu9090933

EFSA (European Food Safety Authority). 2008. Scientific opinion on food additives, flavourings, processing aids and food contact materials on a request from European Commission on safety of aluminium from dietary intake. EFSA Journal, 6: 754. doi: 10.2903/j.efsa.2008.754

EFSA. 2014. Scientific opinion on dietary reference values for chromium. EFSA Journal, 12: 3845. doi: 10.2903/j.efsa.2014.3845

EFSA. 2017. Dietary reference values for nutrients: Summary report. EFSA Supporting Publications, e15121. https://doi.org/10.2903/sp.efsa.2017.e15121

EFSA. 2023. Overview on tolerable upper intake levels as derived by the Scientific Committee on Food (SCF) and the EFSA Panel on Dietetic Products, Nutrition and Allergies (NDA): Technical report. Version 9. EFSA Journal, 21: 111-114. doi: 10.2903/j.efsa.2023.7890

Genchi G, Carocci A, Lauria G, Sinicropi MS, Catalano A. 2020. Nickel: Human health and environmental toxicology. International Journal of Environmental Research and Public Health, 17: 679. doi: 10.3390/ijerph17030679

Horasan BY, Öztürk A. 2021. Evaluation of heavy metal content of salts between Eskıkışla and Ocakbaşı (Kırıkkale) villages. Turkish Journal of Engineering, 5: 29-34. doi: 10.31127/tuje.652452

Jomova K, Alomar SY, Nepovimova E, Kuca M, Valko M. 2025. Heavy metals: Toxicity and human health effects. Archives of Toxicology, 99: 153-209.

Kuru R, Kurt-Mutlu E, Cempel E, Yılmaz S. 2018. Evaluation of dietary boron in terms of health: A retrospective study. Clinical and Experimental Health Sciences, 8: 296-300. doi: 10.5152/clinexphealthsci.2018.955

Kuru R, Yılmaz S, Saçan Ö, Cempel E. 2020. Boron levels in bottled waters in Turkey. In: Proceedings of the 3rd International Eurasian Conference on Biological and Chemical Sciences, Ankara, Turkey, 19-20 October 2020. pp. 763-776.

Li L, Yang X. 2018. The essential element manganese, oxidative stress, and metabolic diseases: Links and interactions. Oxidative Medicine and Cellular Longevity, 2018: 7580707. doi: 10.1155/2018/7580707

Lugendo IJ, Bugumba J. 2021. Heavy metals and essential elements in table salt extracted from Bahi wetlands in Central Tanzania. International Journal of Engineering Sciences & Technology, 13: 21-31. doi: 10.4314/ijest.v13i4.3

Marquès M, Correig E, Capdevila E, Gargallo E, González N, Nadal M, Domingo JL. 2022. Essential and non-essential trace elements in milks and plant-based drinks. Biological Trace Element Research, 200: 4524-4533. doi: 10.1007/s12011-021-03021-5

Nagendra A, Pramod N, Mukund S. 2020. Salt: An overview. Acta Scientific Nutritional Health, 4: 9-16. doi: 10.31080/ASNH.2020.04.0728

National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Food and Nutrition Board. 2001. Dietary Reference Intakes for Vitamin A, Vitamin K, Arsenic, Boron, Chromium, Copper, Iodine, Iron, Manganese, Molybdenum, Nickel, Silicon, Vanadium, and Zinc. Washington, DC: National Academy Press.

National Academies of Sciences, Engineering, and Medicine; Health and Medicine Division; Food and Nutrition Board. 2019. Dietary reference intakes (DRIs): Recommended dietary allowances and adequate intakes, element. In: Stallings VA, Harrison M, Oria M (editors). Dietary Reference Intakes for Sodium and Potassium. Washington, DC: National Academies Press.

Nielsen F. 2021. Nickel. Advances in Nutrition, 12: 281-282. doi: 10.1093/advances/nmaa154

Republic of Türkiye Ministry of Health. 2019. Türkiye nutrition and health survey. Ankara: Tiraj.

Republic of Türkiye Ministry of Health. 2022. Dietary guideline for Türkiye. Ankara: Ministry of Health Press.

Somuncu BP, Topbaş M, Albay M, Çamur D, İlter H, Ayoğlu FN, Altın A, Can M, Demirtaş Y, Açıkgöz B, Aydın F. 2025. Essential and toxic elements in nail samples from fishermen in Turkey. Toxicological and Environmental Chemistry, 107: 155-177. doi: 10.1080/02772248.2025.2450445

Sosa-Baldivia A, Ruiz-Ibarra G, Robles-de La Torre RR, Gordillo-Sobrino G, Tasistro A, Etchevers-Barra JD, Reyna-Santamaría L. 2016. Five causes why boron essentiality on humans has not been confirmed: A hypothesis. Integrative Food, Nutrition and Metabolism, 4: 1-5. doi: 10.15761/IFNM.1000170

Tumolo M, Ancona V, De Paola D, Losacco D, Campanale C, Massarelli C, Uricchio VF. 2020. Chromium pollution in European water, sources, health risk, and remediation strategies: An overview. International Journal of Environmental Research and Public Health, 17: 5438. doi: 10.3390/ijerph17155438

Türkiye Mineral Research and Exploration General Directorate. 2024. Rock salt. Available from: https://www.mta.gov.tr/en/ [Accessed 27 March 2025]

United States Environmental Protection Agency. 2024. Integrated risk information system. Available from: https://www.epa.gov/iris [Accessed 28 March 2025]

Vincent JB, Lukaski HC. 2018. Chromium. Advances in Nutrition, 9: 505-506. doi: doi: 10.1093/advances/nmx021

Witkowska D, Słowik J, Chilicka K. 2021. Heavy metals and human health: Possible exposure pathways and the competition for protein binding sites. Molecules, 26: 6060. doi: 10.3390/molecules26196060

World Health Organization. 2024. Salt intake. Available from: https://www.who.int/data/gho/indicator-metadata-registry/imr-details/3082 [Accessed 25 March 2025]