Scientific Facts on

Boron

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Summary & Details:
GreenFacts

Level 2 - Details on Boron

This Digest is a faithful summary of the leading scientific consensus report produced in 1998 by the International Programme on Chemical Safety (IPCS):
"Executive Summary of the Environmental Health Criteria for Boron (EHC 204)"

The full Digest is available at: https://www.greenfacts.org/en/boron/

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1. What is boron?

Boron is a naturally occurring element. In nature it is found combined with oxygen and other natural elements forming several different compounds called borates. Borates are widely distributed in nature, being present in the oceans, sedimentary rocks, coal, shale and some soils. The average concentration of boron in rocks varies from 5 mg/kg in basalts to 100 mg/kg in shales. In the ocean, the boron concentration is approximately 4.5 mg/liter.

The most important borate products and minerals on the market are borax pentahydrate, borax, sodium perborate, boric acid, colemanite, and ulexite.

Boric acid and many borates are soluble, at low levels, in water and in biological fluids such as saliva and blood. When boric acid or borates are dissolved in these liquids, which have a near-neutral pH, the main molecular species present is boric acid with a small amount of borate anion. The amount of borate anion is greater in more alkaline (or higher pH) solutions.

Sodium perborate, however, is different from the other borates. It reacts with the water in which it is dissolved to give hydrogen peroxide plus metaborate. Because it forms hydrogen peroxide, which has oxidising properties, sodium perborate has chemical and toxicological properties that are somewhat different from those of the other borates.

The method used to measure the boron concentration is quite important.

Click here for information on measuring methods and units for boron [see Annex 1, p. 9]

2. Where is boron found?

2.1 What is the production and use of boron?

The primary source of both boron and borates is the mining of boron-containing minerals such as colemanite, ulexite, tincal, and kernite. Only certain deposits can be mined economically. These are located in arid regions of Turkey and the USA, and also in Argentina, Chile, Russia, China, and Peru.

The total world production of boron minerals was approximately 2 750 000 tonnes in 1994. About 250 000 tonnes of boron, corresponding to 800 000 tonnes of boron oxide (B_2O_3), was present in commercial borate products manufactured from these minerals.

Click here for information on measuring methods and units for boron [see Annex 1, p. 9]

Commercial borate compounds are used in the manufacture of many different commercial products. These include insulation and textile-grade fibreglass, borosilicate glass, fire retardants, enamels, ceramic glazes, frits, laundry bleach (sodium perborate), agricultural fertilizers and herbicides as well as many other applications.

2.2 What are the sources of boron releases to the environment?

Boron enters the environment mainly through natural processes and, to a lesser extent, from human activities.

Natural processes lead to boron releases:
- from boron-containing rocks through weathering;
- from seawater, as boric acid vapour; and
- from volcanic activity and other geothermal releases such as geothermal steam.

Human activities mainly release boron through:
- agricultural use, mainly from the use of borate-containing fertilizers and herbicides;
- burning of domestic waste, crop residues and wood fuel, as boron is present in many plants being necessary for their growth;
- power generation using fossil fuels such as coal and oil;
- waste from borate mining and processing, including the manufacture of glass products. The use of glass products does not release boron, however, as the boron is tightly bound within the glass itself;
- the use of borates and perborates in the home and industry;
- leaching from treated wood or paper; and
- disposal of sewage and sewage sludge.

It is difficult to determine the exact amount of boron which enters the air, soil, or water from many of these sources.

Borates and boric acid are mainly released to **air** through evaporation from the sea and through volcanic activity in the form of vapour and small particles. To a lesser extent, they can be released to the atmosphere during mining operations, glass and ceramics manufacturing, the application of agricultural fertilizers and herbicides, and from coal-fired power plants. However, boron is not present in the atmosphere at significant levels. Borates do not remain for a long time in the atmosphere, as they generally return to the land or sea during rainfall.

Boron added to **soils** from agricultural products, including sewage sludge, is discussed further in section 5.

Boron can be released to fresh **water** such as rivers and also to the water contained within soils. This occurs through weathering processes and, to a much smaller extent, through human discharges such as sewage and treated effluent releases to rivers.

2.3 How does boron react in the environment?

Boron is present in the environment in boron-containing compounds called borates. Borates dissolved in water can adsorb onto, and desorb from, the many different surfaces found in rivers and streams. The amount of borate adsorption depends on the water’s pH and the concentration of borate in the water. Borates dissolved in water are very stable, and do not react with oxygen or other chemicals which may be present in the water, or undergo changes from one type of borate to another. Also, animals and plants are not able to convert borates from one form to another by biological processes.

Boron is also adsorbed onto soil particles. The type of soil determines the degree of adsorption and to what extent the adsorption is reversible or irreversible, i.e. whether boron can be removed again by water running through the soil or not. The soil characteristics which affect the amount and type of boron binding to soil include soil pH as well as the amount of salt, organic matter, iron and aluminium oxides and hydroxy-oxides, and clay present in the soil.

Boric acid, the main form in which boron is present in biological fluids in plants and animals, has only a low ability to move into fat. Laboratory experiments have confirmed that boric acid does not bioaccumulate in animals which live in water. Plants do accumulate boron depending on several factors including the pH of the soil, the temperature, the intensity of the available light, and the concentration of other elements in the soil (e.g. calcium and potassium). However, boron does not biomagnify along the aquatic food chain i.e. it does not accumulate to a greater extent in animals which eat the plants, or in predatory animals which eat these animals.

3. What levels of boron are found?

3.1 What levels of boron are there in the environment?

In **soils**, boron occurs at concentrations ranging from 10 mg/kg of soil up to 300 mg/kg of soil. The average boron concentration is approximately 30 mg/kg of soil. The boron concentration depends on the type of soil, the amount of organic matter, which contains boron, and the amount of rainfall, which can remove boron from the soil.

In **surface water**, concentrations of boron depend on the amount of boron present in the soils and rocks of the drainage area, and on the proximity of the drainage area to the ocean. The ocean provides boron both by the deposition of vaporised boric acid on the drainage area, and by infiltration of boron-containing seawater in tidal regions and estuaries. Surface waters can also receive boron inputs from effluent discharges, both from industrial processes and from municipal sewage treatment. Concentrations of boron in surface water range widely, from 0.001 mg/litre to as much as 360 mg/litre. However, average boron concentrations are typically well below 0.6 mg/litre (see table below).

Table: Average boron in surface water for different regions

Regions of the world	Representative boron concentrations in surface water
Europe, Pakistan, Russia, and Turkey	Mean concentrations below 0.6 mg/litre
Japan, South Africa, and South America	Generally below 0.3 mg/litre
North America	Typical concentrations below 0.1 mg/litre (with only 10% above 0.4 mg/litre)

In **ambient air**, boron concentrations range from less than 0.5 to approximately 80 ng/m^3 of air, with an average for air laying over continental land masses of 20 ng/m^3 of air.

Boron accumulates in **aquatic and terrestrial plants** but does not increase in concentration through the food-chain. Thus animals which eat plants or predators which eat these plant-eating animals do not build up increasing concentrations of boron in their bodies. Concentrations of boron in plants depend on their environment (see table below).

Table: Boron concentrations in plants living in different environments

Type of plant	Boron concentrations in plant material
Submerged aquatic freshwater plants	26 to 382 mg/kg
Freshwater vegetation in which some parts of the plant are above the water surface	11.3 to 57 mg/kg
Terrestrial plants	2.3 to 94.7 (dry weight)

In **marine invertebrate animals and fish**, boron concentrations are similar to the boron levels found in the oceans, i.e. between 0.5 and 4 mg/kg (wet weight). Two **freshwater fish** species have been found to take up very little boron, as the concentrations in their bodies only reached 30% of the level found in the water in which they live.

3.2 What levels of boron are humans exposed to?

Humans are exposed to boron through diet, from drinking water, and from some consumer products including soaps and detergents, body building supplements, bottled water, fertilizers, pesticides, preservatives, and cosmetic, oral hygiene, eye care, and deodorant products. They may also, to a much smaller extent, ingest boron from the soil or breathe it in with the air.

Table: Estimated average daily human of boron from different sources

Sources of human exposure to boron	Average daily intake of boron
Diet	1.2 mg per day
Drinking-water	0.2 - 0.6 mg per day
Consumer products	0.1 mg per day
Soil	0.0005 mg per day
Air	0.00044 mg per day
All sources combined	**1.5 - 1.9 mg per day**

Within the **diet**, the richest sources of boron are fruits, vegetables, pulses, legumes, and nuts. Dairy products, fish, meats and most grains contain very little boron.

Click here for a table showing "Boron content of some common foods" [see Annex 2, p. 10]

When groundwater and fresh surface water are treated for **drinking-water** purposes, boron is not removed in the treatment.

Workers in borax mines and refining plants, or in industries which use borates to manufacture other products, may be exposed to boron during their work. These industries include the manufacture of fibreglass and other glass products, and the production of cleaning and laundry products, fertilizers, pesticides, and cosmetics.

Inhalation of dusts which contain boron is the most significant route of exposure at work for workers in these industries. Dermal absorption of boron may also occur if damaged skin is in contact with boron compounds.

4. What are the effects of boron on humans and mammals?

4.1 How does boron act in humans and mammals?

Boron appears to act similarly in humans and mammals in the following respects:

a) Once ingested, borates are almost completely **absorbed** in the gut and appear rapidly in the blood and body tissues.

b) In mammals, boron is **distributed** evenly throughout the body fluids. Unlike soft tissues and blood, bone takes up boron selectively to give levels more than four times higher than in blood serum. Boron also remains longer in bone, before elimination.

c) Boric acid is not **metabolised** (transformed) within the body. Thus the types and relative amounts of boron-containing compounds in the body will be the same in all mammals. This facilitates comparisons between work with humans and other mammalian species.

d) Boron is eliminated by the same route and at the same speed in humans and rats, with more than 90% of boron being eliminated through the urine and with half of the boron being eliminated in 24 hours or less.

Rats are the main species used in laboratory studies to determine the no-observed-adverse-effect level (NOAEL) of a substance. These similarities in the way boron acts in humans and rats increase the reliability of predicting effects in humans from effects in rats.

4.2 What are the effects of boron on laboratory animals?

In laboratory animals, boron mainly affects the reproductive system and the development of the fetus.

In rats, the no-observed-adverse-effect level (NOAEL) for boron intake is 9.6 mg/kg body weight per day. The first effect which becomes apparent at greater intake level is reduced fetal body weight. At a boron intake level of about 13 mg/kg maternal body weight per day, the weight of rat fetuses is slightly reduced, and rib anomalies may be present. At approximately 55 mg/kg body weight per day rats experience changes in the testicles and become sterile.

In the rabbit, malformations of the heart and the circulatory system can be seen at boron intake levels of approximately 25 mg/kg body weight per day.

In the mouse, fetal body weight can be affected at approximately 80 mg/kg body weight per day.

Table: Boron levels at which laboratory animals can be affected

Type of animal	Type of effect	Daily intake of boron
Rat	No effect is seen. This is the NOAEL for the Rat.	9.6 mg/kg body weight per day
Rat	The weight of fetuses is slightly reduced, and rib anamolies may be present.	13 mg/kg maternal body weight per day
Rat	Changes in the testicles which lead to sterility	55 mg/kg body weight per day
Rabbit	Malformations of the heart and the circulatory system	25 mg/kg maternal body weight per day
Mouse	Fetal body weight can be affected	80 mg/kg maternal body weight per day

Studies on mice and rats showed no evidence of carcinogenicity of boric acid.

4.3 What are the effects of boron on humans?

Because of the lack of human data and the limited amount of animal data, the EPA has classified boron as "not classifiable as to human carcinogenicity" in 1994.

Only a few studies on humans have investigated health effects associated with exposure to boron compounds. These show that exposure can be associated with short-term and reversible **irritant effects** on the upper respiratory tract, nasopharynx, and eyes. The sole long-term study did not identify any long-term health effects.

Two studies on people exposed to boron found no effects on human fertility and no statistically significant change in the relative number of boys and girls born. No studies have yet investigated other reproductive outcomes, such as time-to-pregnancy, conception delays, spontaneous abortions, and sperm quality. In order to identify populations which might be sensitive to boron exposure, and to evaluate reproductive effects more fully, further study of the role of other lifestyle or behavioural factors in relation to health and fertility is needed.

5. What are the effects of boron on organisms in the environment?

The effect of boron has been determined for several types of organisms in the environment, but more information is available for some types of organism than for others. Some of the information covers the effects of short-term exposure to boron, while other information focuses on long-term or chronic exposure. The information may be available for several types of organism within a group – for example, for several types of invertebrates – or it may be available for only one type. The amounts and types of information available for different species are important in the overall judgement of the relative sensitivity of environmental organisms to boron in the environment.

The table below shows the information available for different organisms, and the types of tests and the approximate number of different species for which these tests were carried out.

Table: "Reported critical boron levels for several types of environmental organism"

Type of organism	Type of effect(s) reported	Boron concentration in the water
Bacteria	Mixture of **acute** and **chronic** effects, for several types of bacteria	8 - 340 mg/litre (mainly above 18 mg/litre)
Protozoa	First very small effects, for 2 types of protozoa	0.3 - 18 mg/litre
Freshwater green algae	Highest concentration with no effect (**NOEC**), for several types of algae	10 - 24 mg/litre
Blue-green algae	First very small effect for 1 type of blue-green algae	20 mg/litre
Invertebrates	**Acute** effects for several types of invertebrates	95 to 1376 mg/litre (mainly 100-200 mg/litre)
Water flea (Daphnia magna)	Highest concentration with no effect (**NOEC**), found in many **chronic** tests for this one invertebrate type	6 - 10 mg/litre
Fish	**Acute** effects in several types of fish	10 to nearly 300 mg/litre
Rainbow trout	Chronic tests with standard laboratory water (**NOEC**)	0.009 - 0.103 mg/litre
Rainbow trout	Chronic tests in several natural waters (**NOEC**)	0.75 - > 18 mg/litre

The data in the table show that **bacteria** are much less sensitive to boron, compared to other chemicals. **Protozoa** are somewhat more sensitive. **Algae**, for which boron is an essential nutrient, also have low sensitivity to boron. **Invertebrates** also have a low boron sensitivity, as determined from many long-term studies. **Fish** are the most sensitive species to boron.

The experts assembled by the World Health Organization (WHO) to write the IPCS document decided, based on the sensitivity of the various tests and the numbers of tests for the different types of organisms, that a boron level of 1 mg/litre water would cause no adverse effect on the environment. As well as information on the toxicity of boron in the aquatic environment, information is also available for one predator which eats aquatic species. In mallard, a **water fowl** species, boron can affect duckling growth at dietary intake levels of 30 - 300 mg/kg weight of animal, and can reduce survival at 1000 mg/kg weight of animal.

Boron is an essential micronutrient for **plants**, but different plant species require different boron levels for optimum growth. Boron plays several roles within the plant cell: in cell division, in the metabolism, and in the cell membrane. As a result, boron (in the form of borates) occurs naturally in fruits, nuts, and vegetables (see table on Boron content of some common foods in question 3.2).

In plants, there is only a narrow margin between boron deficiency and excess boron uptake leading to toxicity. Boron deficiencies in terrestrial plants have been reported in many countries. Boron deficiency occurs when boron leaches out of the soil, particularly in humid regions with light-textured, acid soils. Boron excesses usually occur in soil solution, i.e. the water found in the soil containing soluble material, from geologically young deposits, arid soils and soils derived from marine sediments. It also occurs in soils contaminated by human activities, such as releases from coal-fired power plants and mining operations. Irrigation water containing boron is one of the main sources of high boron levels leading to toxicity on agricultural land.

6. Conclusions

Boron is a naturally occurring element that is found in nature in compounds called borates. Borates are found in the oceans, sedimentary rocks, coal, shale, and some soils. Borates are naturally released into the environment from the oceans, volcanic activity and other geothermal releases such as geothermal steam, and weathering of clay-rich sedimentary rocks. Boron is also released, to a lesser extent, from sources due to human activity.

Boron is an essential micronutrient for plants, with levels of boron required for optimum growth depending on the plant species. Boron deficiency in terrestrial plants has also been observed in many parts of the world. In some plants, there is but a narrow range between boron deficiency and toxicity.

The risk of adverse effects of boron on the aquatic ecosystem is low, because general levels of boron in the environment are below the no-effect concentration (1 mg/litre water). In a few boron-rich environments, natural levels will be higher. However, it is reasonable to assume that aquatic organisms in such habitats are adapted to the local conditions.

Humans are primarily exposed to boron through food and drinking-water. The mean daily intake of boron via the diet is about 1.2 mg per person per day and the estimated mean boron concentration in drinking-water is between 0.1 and 0.3 mg/litre. In humans and animals, most of the boric acid and borate are absorbed from the gastrointestinal and respiratory tracts and rapidly excreted in the urine.

Animal experiments have shown that boron in the form of both boric acid and borate can harm reproduction and development at levels that are approximately 100 to 1000 times greater than normal exposure levels. There is insufficient toxicity data on humans. The Tolerable Intake (TI) of boron was set at 0.4 mg/kg body weight per day.

These conclusions have led to the formulation of a series of recommendations.

Annex

Annex 1:
Boron - Units and Measurement Methods

Units & conversion factors - Measurement Methods

Boron - Units & conversion factors

Boron which is measured in environmental samples may either be reported in:

- **units of mass per volume**, such as µg/l or mg/m, or
- **parts per million by weight**, or ppm

When describing concentrations of boron in air as a volume fraction:

1ppm. = 0.4421 mg/m^3 (or 1 mg/m^3 = 2.262 ppm.).

Sometimes, however, the amount of boron used in toxicity testing can be reported as

- the **total weight of the boron-containing compound** - such as boric acid - used in the test, rather than as the weight of only the boron present in the sample.

It is important that the same type of unit is used when amounts of boron in different samples are compared.

Table of conversion factors:	
Boron-containing compounds	**weight of Boron in 1 gram of compound**
boric acid	0.175 g
borax	0.113 g
anhydrous borax	0.215 g
sodium perborate tetrahydrate	0.070 g
sodium perborate monohydrate	0.108 g
metaboric acid	0.247 g

Finally, the amounts of boron measured in different samples may refer to different sample preparation techniques.

Dried samples: Since the amount of water in a biological tissue can vary, many samples are dried thoroughly before measurements are made. These samples will have units such as µg/g **dry weight** of sample.

Wet samples: In some work it is not appropriate that the samples be dried, and in these cases the wet weight of the sample will be used, with units such as µg**/l wet weight.**

It is important that the same units are used if comparisons are to be made between different samples.

Source & © based on the full IPCS document Environmental Health Criteria (EHC) 204, Section 2.3: Conversion factors [see http://www.inchem.org/documents/ehc/ehc/ehc204.htm#SectionNumber:2.3] (1998)

Units & conversion factors - Measurement Methods

Boron - Measurement Methods

Extraction: In order to measure the amount of boron present in water, soil, or in biota such as plants or other environmental species, the boron is usually removed from the sample by a process called extraction. Hot water is used to extract boron from soil. Acid and chloroform are used to extract boron from water, while acid can be used to extract boron from biological samples. Error can be introduced into the measurement process if extraction is not complete.

Analysis: The solution containing the extracted boron is then analysed, to determine the amount of boron originally present in the sample. For the low levels of boron present in environmental samples, sensitive measurement techniques are needed. The best techniques use ICP, or Inductively Coupled Plasma, methods, with either Atomic emission spectroscopy (AES) or Mass spectrometry (MS) used to detect the boron. ICP-MS is the most sensitive, as shown in the table below. In addition, it requires only a small volume of sample for the measurement.

Overview of Analytical Techniques		
Analytical Technique	**Samples for which the technique is useful**	**Detection limits**
ICP-AES	Bone, plasma, food, tumour, blood, liver, skin, cell suspensions, wastewater, and fish tissues	5 to 50 µg boron/litre of solution analysed
ICP-MS (with direct nebulization)	Plant, rat, and human tissue	1 ng/g (or 1 µg boron/kg material)
ICP-MS	fresh and saline water, sewage, wastewater, soils, plant samples and all biological materials	0.15 µg boron/litre sample.
Azomethine-H*	Environmental water samples	20 µg boron/litre of solution analysed
Curcumin*	Environmental water samples - nitrate, chloride, and fluoride will interfere with method	100 - 1000 µg boron/litre of solution analysed
Neutron Activation with MS analysis	Blood and other biological samples. Also freeze dried leaves, human erythrocytes, and food items	10-8 g boron per g of sample analysed (or 10 µg boron/kg of sample analysed)
* Method must be used with caution, as interference is common in biological and environmental samples.		

IPC and neutron activation methods shown in the table above require expensive analytical equipment. For this reason, the older (and less expensive) **colorimetric techniques** based on changes in the colour and intensity of certain dyes when boron is present are sometimes still used. Some information on these techniques is also given in the table above. However, many substances, present in biological and environmental samples, can interfere with these colorimetric measurements. For this reason, the World Health Organization (WHO) ECH report states that the **IPC methods** are preferred for the analysis of the low levels of boron found in biological and environmental samples, and that colorimetric methods must be used with caution.

Source & © based on the full IPCS documentEnvironmental Health Criteria (EHC) 204, Section 2.4: Analytical methods [see http://www.inchem.org/documents/ehc/ehc/ehc204.htm#SectionNumber:2.4] (1998)

Annex 2:

Boron in Food

- Boron content in food
- How much food would I have to eat each day to reach the Tolerable Daily Intake (TDI)?

Boron content in food

Boron content of some common foods		
Food	Boron concentration in mg/kg, fresh weight basis	
	Hunt et al. (1991)	Anderson et al. (1994b)
Fruits		
Apple, red with peel, raw	2.73	2.38
Apple juice	1.88	2.41
Apple sauce	2.83	1.04
Banana, raw	-	3.72
Cherries, dark	1.47	0.92
Grape juice	2.02	2.06
Orange juice	0.41	1.59
Peaches, canned	1.87	-
Pears, canned	1.22	-
Dried fruits		
Dates	9.2	-
Prunes	27	21.5
Raisins	25	19.0
Vegetables		
Beans, green	0.46	1.56
Broccoli, flowers	1.85	-
Broccoli, stalks	0.89	-
Lettuce, iceberg	<0.015	-
Carrots, canned	0.75	-
Nuts		
Almonds	23	-
Hazelnuts	16	-
Peanuts	18	13.8
Meats		
Beef, round, ground, raw	<0.015	<0.05
Chicken, breast, ground, raw	<0.015	0.09
Turkey breast	<0.015	-
Milk & milk products		
Cheese, cream	<0.015	0.19
Milk, 2%	<0.015	0.23
Cereal grain products		
Bread, white, enriched	0.20	0.48
Cornflakes fortified	0.31	0.92
Flour, wheat, white	0.28	-
Noodles,egg, dry, enriched	0.37	-
Rice, white, instant	<0.015	-
Spaghetti, dry, enriched	<0.015	-
Miscellaneous		
Catsup	0.85	1.39
Eggs, homogen-ized	<0.015	0.12
Honey	7.2	6.07
Jelly, strawberry	0.41	-
Jelly, grape	1.47	1.86
Sugar, white	<0.015	0.29
Beverages	Boron concentration in µg/ml	
Wine	-	3.5
Beer	1.8	0.13

Source & © IPCS Environmental Health Criteria for Boron (EHC 204), chapter 5.2.4 "Dietary intake" [see http://www.inchem.org/documents/ehc/ehc/ehc204.htm#SubSectionNumber:5.2.4]

How much food would I have to eat each day to reach the Tolerable Daily Intake (TDI)?

The amount of food which has to be eaten per day to reach the TDI depends

- on the amount of boron in each food, and
- on the body weight of the individual adult or child.

The US EPA has established a standard body weight of 70 kg for an adult, and has also established median body weights of 13.2 kg for a child aged 1-3 years, and 24.9 kg for a child aged 1-14 years (Ref US-EPA, 2002).

small children (1-3y) - children (1-14y) - adults

Small children: Foods with a relatively high boron content which are suitable for small children include bananas (up to 3.7 mg boron/kg), apples (up to 2.7 mg boron/kg) and dried fruits such as prunes and raisins (at up to 27 mg boron/kg). A small child weighing 13.2 kg would need to eat more than sixty times the average daily amount of these foods each day to reach the TDI, as shown in the table below.

Boron Consumption for a small child (13.2 kg body weight)		
Food	**Daily amount needed to reach the TDI**	**Average daily amount eaten (age 1-2) (REF US EPA 2002)**
Bananas	1.4 kg	0.022 kg
Apples	1.9 kg	0.024 kg
Dried Fruit (Prunes, Raisins)	0.2 kg	0.002 kg

Children: Older children are also able to eat nuts, such as peanuts and almonds, which have boron contents of up to 23 mg boron/kg. The table below shows that the median child aged 1-14 years and weighing almost 25 kg would need to eat more than 80 times the average daily consumption of these foods to reach the TDI.

Boron Consumption for a mid-range child (24.9 kg body weight)		
Food	**Daily amount needed to reach the TDI**	**Average daily amount eaten (age 6-14) (REF US EPA 2002)**
Bananas	2.7 kg	0.008 to 0.011 kg
Apples	3.7 kg	0.021 to 0.028 kg
Dried Fruit (Prunes, Raisins)	0.4 kg	Less than 0.0005 kg
Nuts (Almonds, Peanuts)	0.4 kg	0.005 kg

Adults: Adults weigh more than children, and thus have to eat even more boron-containing food to reach the TDI. Detailed average consumption figures for different types of food are not given in the EPA report for adults, but the values given for male children aged 12 to 19 should be comparable, or perhaps higher than the average adult consumption. The table below shows that the average adult would need to eat more than 200 times the average daily amount consumed by a teenaged male in order to reach the TDI for boron.

Boron Consumption for an adult (70 kg body weight)		
Food	**Daily amount needed to reach the TDI**	**Average daily amount eaten (male age 12-19) (REF US EPA 2002)**
Bananas	7.5 kg	0.008 kg
Apples	10.3 kg	0.013 kg
Dried Fruit (Prunes, Raisins)	1.0 kg	0.001 kg
Nuts (Almonds, Peanuts)	1.2 kg	0.005 kg

However, it would be possible for an individual adult or child to consume enough food with a high boron content to reach the TDI, on any specific day.
This would be most likely for a small child, for whom consumption of over 200 g of prunes or raisins on a single day would exceed the TDI for boron on that day.

However, the TDI represents a tolerable daily intake for a life-time exposure. Occasional exceeding of the TDI may not necessarily lead to health consequences, provided that the averaged intake over longer periods remains below it.

Source & © Dr. Kay Fox for GreenFacts, based on a comparison between data from

- *IPCS*
- *U.S. Environmental Protection Agency (US EPA), National Center for Environmental Assessment, Child-specific exposure factors handbook (Interim Report) [see http://cfpub.epa.gov/ncea/cfm/recordisplay.cfm?deid=55145] (2002).*