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Environmental boron contamination in waters of Hisarcik area in the Kutahya Province of Turkey

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Abstract

Our aim was to determine boron levels in waters of rich boron mine areas in Turkey. There is a naturally occurring high level of boron in the ground waters of some parts of Turkey. Our study area is Hisarcik village in the Kutahya Province of Turkey which has a large number of boron mines. Boron occurs in combined form, usually borax ($Na_2B_4O_7.10H_2O$) and colemanite ($Ca_2B_6O_{11}$–$5H_2O$). Water samples were collected from many springs in order to determine boron concentrations and the amount of boron that is exposed to 88 samples from the drinking water (tap water), 37 from ground water and 257 from stream or pond water (surface water). Urine samples taken from 42 residents in this area were analyzed for boron and compared with its levels in drinking waters. The inductively coupled plasma/mass spectrometry (ICP/MS) method was used for the analysis of boron concentrations. Water boron contents at differing locations of this area ranged from 2.05 to 29.00 mg B/l. Mean value of boron was 10.20 ± 4.08 mg B/l. Total urinary boron excretion was ranged from 0.04 to 50.70 mg B/l and mean value was 8.30 ± 10.91 mg B/l. Current information on sources, occurrence, pollution potential and toxicity of environmental boron is discussed.

Keywords: Boron; Drinking water; Environment

1. Introduction

Boron is a naturally occurring dark brown/black substance found throughout the environment. It can also be found naturally in soil concentrations of 5–150 parts per million (ppm). Boron does not occur free in the environment, it is always bound to oxygen. Some areas of Turkey are naturally high in boron minerals. The highest concentrations of boron are found in sediments and sedimentary rock. Turkey is one of the major boron exporters of the world. Boron is used in a variety of products including glass and glass products, cleaning products, agrochemicals, insecticides, flameproofing compounds and corrosion inhibitors.

The term boron is used to express data as the equivalent boron (B) content of a borate, and is not intended to mean elemental boron. Atomic weight of boron is 10.811 and its solid state at 298 °K. Boron's melting point is 2349 °K and boiling point is 4200 °K. It has properties, which are borderline between metals and non-metals (Information Ventures, Inc., 1995).

Boron is an essential nutrient for plants, but can be toxic to organisms when accumulated in high concentrations. Boron is widely distributed in nature in low concentrations, and is usually <0.1–0.5 mg B/l in surface freshwaters; but its higher concentrations are measured in a few areas. Its major release into the environment is through weathering processes and wastewater discharge (Howe, 1998; Coughlin, 1998).

A tolerable daily intake of boron for a 60 kg person was calculated to be 34 mg B/day (WHO, 1993). As there are rich natural boron sources in the Hisarcik region of Turkey it is assumed that boron levels in water used by residents is higher and those people are exposed to the high boron intake from drinking water and foods that are grown in that region.

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2. Methods

Water samples were collected from many springs in order to determine boron concentrations to 88 samples from the drinking water (tap water), 37 from ground water, and 257 from stream or pond water (surface water). Twenty-four hours urine samples taken from 42 volunteer residents were selected randomly in this area and all samples were analyzed for boron levels. The samples are not contaminated with boron from equipment, clothing, skin or dust, when collecting from water and urine, and when the storage of samples in glass (borosilicate glass) containers is avoided.

The inductively coupled plasma/mass spectrometry (ICP/MS) method was used for quantitative analysis of boron concentrations (EPA, 1994). Descriptive analysis was applied to data. Current information on sources, occurrence, pollution potential and toxicity of environmental boron is reviewed and discussed with the knowledge of medical literature in respect to the effects of boron.

3. Results

Turkey has the largest natural boron reserves in the world and approximately 2% of Turkish population lives in these regions. The study region (Hisarcik) is a small town of approximately 2000 people located on the edge of a large, open pit mine, which produces borax ($Na_2B_4O_7.10H_2O$) and colemanite ($Ca_2B_6O_{11}–5H_2O$). Most of the adult population works in borax mines and in agriculture or stockbreeding animals. A lot of spring-fed fountains leading from the mine pit to the center of town are located in Hisarcik. Domestic waters are piped into homes from groundwater sources on the other side of a hill from the mine. The people of Hisarcik routinely use ground water for food and tea preparation, brushing teeth, bathing, washing clothes, cleaning dishes, and watering gardens. Some people also used ground water for drinking.

Boron concentrations established in the samples taken from all water sources of the region are shown in Table 1. Boron levels in water were found as minimum 0.03 mg B/l, maximum 17.50 mg B/l, and the mean level of boron was 10.20±4.08 mg B/l. Only two water samples' boron level were less than 0.3 mg B/l and 99% of the samples tested had boron levels higher than that of the EPA standard. In this study, total urinary boron excretion was also measured in order to evaluate the quantity of boron intake by water and/or food. Tests showed total urinary boron excretion ranging from 0.04 to 50.70 mg B/l (mean value was 8.30±10.91 mg B/l.). The data did not show any correlation between boron in drinking/cooking water and individual total urinary boron excretion in volunteers.

4. Discussion

Boron is a naturally occurring element widely present in the environment in the form of borates. Generally, environmental concentrations found in surface water are below levels identified as toxic to organisms. Levels of boron in fresh water in the USA tend to average about 0.1 mg B/l however; they are higher—between 5 and 15 mg B/l—in the western part of the country. (Butterwick et al., 1989) The natural daily dietary intake of borate through food and beverages forms an important part of the daily exposure for animals and human beings. The daily intake of boron by man may vary widely, depending on the proportions of various food groups in the diet. For example, fresh vegetables, fruit and wine have relatively high boron contents. There may also be a considerable elevation in the daily boron intake from drinking water and mineral water. Boron was found to be neither genotoxic nor carcinogenic (WHO, 1993). However reproductive and developmental aspects are taken as a basis for some risk assessment, since it represented the most sensitive end-points for these compounds. In animals, chronic low-level boron exposure has been shown to cause reduced growth, cutaneous disorders and suppression of male reproductive system function (Benderdour et al., 1998). The fertility characteristics were investigated also in this region of Turkey by the researcher group of Ankara University Medical School and no negative effects on reproductive health were found (Çöl et al., 1999).

According to the US-EPA, Office of Water (EPA, 1996), the reference dose of boron for a 70 kg adult is

Table 1
Boron concentrations in water samples of the study region (mg B/l)

	Sample sizes	Minimum–maximum	Mean±S.D.
Drinking water (tap water)	88	0.03–3.39	1.70±0.92
Ground water	37	0.08–0.47	0.091±0.22
Non-drinking stream or pond water (surface water)	257	0.56–17.50	11.11±03.18
Total	382	0.03–17.50	10.20±4.08

0.9 mg/kg/day. This is an estimate of a daily exposure to the human population that is likely to be without appreciable risk of deleterious effect over a lifetime. The current interim maximum acceptable concentration for boron in drinking water, according to Health Canada, is 5.0 mg/l (Health Canada, 1996). The National Academy of Sciences (NAS, 1980) recommends a guideline of less than 1.0 mg B/l for drinking water. In the USSR, the guideline is less than 0.5 mg B/l (Seal and Weeth, 1980), and according to Puls (1994), the recommended maximum level for humans is less than 5.0 mg B/l. Several individual states in the USA have set drinking water guidelines for boron ranging from 0.006 to 1.0 mg/l (Colorado Public Health, 1997).

In this study higher boron levels than the acceptable values are found in the water. The average boron amount in all water samples was 10.20±4.08 mg B/l. This value is much higher than the limits determined as 0.3 mg B/l by WHO and US Environmental Protection Agency (EPA) (WHO, 1993; EPA, 1996). Long-term usage of water taken from these sources is very important from the point view of the possible chronical toxicity of boron. The people of Hisarcik usually work in borax mines and they typically spend their lives in this region.

They eat the locally grown food and use the ground water for drinking or food preparation. For that reason, they can be exposed to chronic boron intake through both food and water, and therefore this study region is very suitable for epidemiological researches about boron exposure. This characteristic is verified with the high boron levels in the water and high total urinary boron excretion. The first results of our study show there are no remarkable findings of toxicity. It is considered that chronic boron exposure does not have important toxic effects because there is no established clear increase of disease among the people in the region (Çöl et al., 1999, 2000) It is concluded that current boron levels in Hisarcik waters would not be expected to pose any health risk and adverse effect to the public.

The presence of high concentrations of boron in community water supplies has been reported as a localized problem in certain areas of some countries. There are many publications which report on the positive effects of low doses and negative effects of high doses of boron on health in experimental studies. The mechanisms underlying these effects and available data on dose–response relationships are uncertain. However the exact toxic boron intake level is not clearly known. It has been observed that high doses of boron exposure may have an effect on acute and chronic toxicity to testis and reproductive functions. On the other hand, low doses of boron have a positive effect on the healing of wounds and cerebral functions and by affecting calcium metabolism serves to activate bone and mineral metabolism. Furthermore, it has anti-osteoporotic, anti-inflammatory, anti-coagulating, anti-neoplastic and hypolipemic effects (Chapin et al., 1997; Çöl et al., 2000; Hall et al., 1994; Hunt et al., 1997; Mecham et al., 1995; Nielsen et al., 1987; Wilson and Ruszler, 1997, 1998).

The mean amount of boron in the 24-h urine samples was calculate from mean urine boron concentration and mean 24-h volume 12.6 mg B/day (8.3 mg B/l) for 42 volunteers randomly selected from the study region. Boron, taken through food and water, is absorbed rapidly from the gastrointestinal tract and it is eliminated very rapidly. Almost all of it is thrown out by the urinary system. Fifty percent of the absorbed boron is eliminated on the first day, and the rest of it is completely eliminated in 3–7 days (Ishii et al., 1993; Mastromatteo and Sullivan, 1994). Urinary boron output reflects boron intake and the urinary levels of boron are useful as an indicator of total daily boron intakes. As a conclusion the profits of some mines to industry are certainly very important; however while using these industrial sources we must be careful about environmental health and take some precautions to get rid of the harmful effects on public health.

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