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# The Effects of Boron Mining on Boron Content of Soil-Sediment and Plants

**Sonay Sozudogru Ok**
Department of Soil Science and Plant Nutrition, Faculty of Agriculture,
University of Ankara
Ankara /Turkey

**Aysen Akay**
Deparment of Soil Science and Plant Nutrition, Selcuk University, Faculty of Agriculture
Konya /Turkey

## ABSTRACT

Naturally, the amount of Boron and also Arsenic which sometimes exists together with boron is higher in the soils of the basins where boron deposits exist compared to other soils. This is mainly because of the existence of inorganic components which come out as the result of the decomposition of rocks in the composition of soil. On the other hand, the increase in the amount of B element in the environment, which released during mining activities, is of anthropogenic origin. This situation, however, causes environmental pollution. For this reason, it is necessary to distinguish between these two types of increase and take measures to protect the soil and water resources. The effect of the two different boron mines (X and Y) which exist in this region on the environment has become highly questionable. In this study, B concentration of the soil and plant samples taken from Emet and Hisarcık basin were determined and the dimensions of the natural and anthropogenic effects were investigated. As the result of the examinations performed, it was found that the total boron content of the soils was between 20-2000 mg $kg^{-1}$ and their plant-available B content was between 0.01-744.39 mg $kg^{-1}$. It was observed that these values were the highest near the boron mine as those of the total B content and the values decreased as the distance of the soil from the mine increased. These values are substantially higher than the tolerable limit values.

## Keywords

Boron, boron mine, plants, environmental pollution

## 1. INTRODUCTION

The known boron reserves of Turkey were accumulated in lacustrine environments in the Miocene geological period in the regions where volcanic activities took place in the Tertiary period of Western Anatolia. Elements such as As, S, Li, Sr, Sb, Pb and Mn also commonly exist in various amounts in addition to the rich boron reserves located in Western Anatolia. The common source of these elements existing in Neogene basins is the volcanic activities which were effective during the formation of these basins and hydrothermal or thermal springs that were related to these activities.

In terms of its geological and tectonic setting, Emet and Hisarcık region, which is the place where the research study presented in this paper was conducted, is a north-south elongated basin in which volcano-sedimentary and sedimentary lake deposits exist. This sedimentary basin hosts part of the richest boron ores of Turkey. It is also known that Ca-As-borates also exist in this region (Helvacı and Alonso 2000; Helvacı, 2008). Boron toxicity is one of the most important micronutrient problems affecting plant growth in Turkey. Especially, in Central Anatolia, where cultivation of wheat is very common, boron toxicity is well-documented (Sillanpaa, 1982; Kalaycı *et al.* 1998). In many places in the world, even natural waters contain small amounts of boron (100 ppb or less). But it should be kept in mind that this level also varies from location to location. On the other hand, the boron content in the soil changes between 1-476 ppm Boron content in the soil is considered to be 9-85ppm on average. Depending on the main rock, boron content in the soil exhibits a large variation (Kabata-Pendias and Pendias 2001). The known borate deposits in Turkey particularly exist in Kırka (Eskisehir), Bigadic and Susurluk (Balıkesir), Kestelek (Bursa), Hisarcık and Emet (Kütahya). In a study conducted in Hisarcık and Emet basin, where these deposits exist, it is stated that B concentration varied between 65-210 ppb. In ground waters, however, B concentration varied between 280-3025 ppb (Helvacı 2008). The results show that the two boron enterprises existing in this region particularly cause environmental pollution in addition to the effect of natural geological pollution, and the enterprises have a significant role on the B concentrations of the Emet brook (Atabey and Ünal 2008). In a study conducted on the geochemistry of Emet and Hisarcık Basin, it is reported that the basic values for boron were found to be 10 ppm, anomalies up to 370 ppm were determined on the areas above ore lenses (Özkul *et al.,* 2008). People can be exposed to boron in food, mainly vegetables and fruits that boron is an essential element for plants. The average daily intake of boron for adults is 1 mg. One might exposure Boron in air has irritation of the nose, throat, and eyes. Exposure by ingestion affect the stomach, intestines, liver, kidney, and brain and can eventually lead to death depending on the time period (ATSDR, 2010). In the present study, which was conducted by taking into consideration the high toxic effects of boron mentioned above, the existence of B was investigated in the soils of Emet and Hisarcık region and in the plants cultivated in these soils. This area is a sedimentary basin which hosts part of the richest boron ores in Turkey.

## 2. MATERIAL VE METHOD

Soil and sediment samples were taken from the places mentioned in Table 1. The following parameters were analyzed in these samples: Soil pH and EC in saturation extracts (Richards, 1954), organic matter (Nelson and Sommers 1982), texture (Bouyoucos 1951), Boron (total and water soluble) (by ICP-MS ACME Analytical Labs, Vancouver, BC) (Table 1). Plant samples that were collected in the fields and gardens from which the soil samples were taken were subjected to B analysis using ICP-MS. Samples number 8 ,9, 10, 11 and 13 were taken from the vicinity of Mugla Province for comparison where no boron enterprise.

**Table1: Some properties and boron content of soils**

| Soil Sample | pH (extract) | EC (extract) (dS/m) | Org. Mat. (%) | Texture | Total B (mg $kg^{-1}$) | B (water soluble) ( mg $kg^{-1}$) |
|---|---|---|---|---|---|---|
| 1. The sediment sample left by the Emet stream at the point where the brook passing through the X-Boron enterprise joins the stream | 8.28 | 5.22 | 0,38 | SL | 375 | 259,9 |
| 2.The soil of the vegetable garden located on the bank of the discharge channel of the thermal power plant | 8.60 | 1.71 | 6,16 | C | 25.1 | 4,39 |
| 3. The soil of the corn field located on the west bank of the Emet stream at the point where the brook passing through the X- Boron enterprise joins the stream | 8.19 | 3.29 | 5,43 | C | 216 | 83,70 |
| 4.The waste soil of the X Boron enterprise on the bank of the Emet stream to the east of the Yoncaağac Village of Hisarcık District | 8.10 | 4.57 | 1,10 | C | >2000 | 744,39 |
| 5.The soil of the field on the left side of the road at the entrance of the İğdeköy Village of Emet District at a distance of 150 m from the village | 8.44 | 0.53 | 0,55 | CL | <20 | 3,54 |
| 6.Hacıosmanın Damları Village. The soil of the field on the bank of Emet stream where the wells that provide drinking water to Emet District | 8.63 | 0.87 | 0,62 | SCL | 21 | 1,72 |
| 7.To the south of the thermal power plant, 100 m to the west of the center of Bozhüyük village. Mud from the discharge canal of the thermal power plant. | 8.20 | 5.07 | 1,02 | L | 40 | 1,45 |
| 8.The entrance of the Kütahya-Dulkadir Village | 8.14 | 2.21 | 7,03 | C | <20 | 1,13 |
| 9.Mugla-Dalaman Dömbek site soil sample | 8.36 | 0.83 | 1,50 | C | <20 | 0,11 |
| 10.Mugla-Ortaca Dikmekavak soil sample | 8.64 | 1.53 | 1,16 | Cl | <20 | 0,14 |
| 11.Mugla-Dalaman Türkocagı site soil sample | 8.59 | 1.40 | 1,64 | SCL | <20 | 0,01 |
| 12.The soil of the field at the entrance of Kırgıl Village | 8.18 | 3.62 | 0,32 | SL | <20 | 0,20 |
| 13.The soil of the field near Mugla-Yatağan Dipsiz Site Thermal power plant and the water well providing drinking water to Yatağan | 8.54 | 0.74 | 1,46 | SL | <20 | 0,07 |
| 14.The soil of the field on the way to Doğanlar 200 m ahead of Emet stream bridge located on the right of the road | 8.54 | 1.04 | 0,92 | SL | <20 | 0,18 |
| 15. Soil sample taken from the field located in front of the wastes of Y- Boron enterprise, Hisarcık- Emet stream. The field is irrigated with the water from the Emet stream. | 8.52 | 1.20 | 2,37 | CL | 167 | 24,42 |
| 16.Sample taken from the garden located on the left of the entrance of Doğanlar Village of Emet District | 8.42 | 1.42 | 2,08 | SL | <20 | 0,95 |
| 17.Garden soil from the center of Calcagıl Village | 8.53 | 1.06 | 5,52 | CL | <20 | 0,62 |
| 18.Soil sample taken from the field in Mollabükü site located on the road to Hisarcık 5 km from Emet | 8.33 | 1.05 | 0,66 | SCL | <20 | 2,99 |

## 2. RESULTS AND DISCUSSION

pH ve EC values of soils were between 8.10- 8.66 (slightly alkaline and alkaline) and, 0.53-5.22 dS $m^{-1}$ (medium to low salt content). Textures were clayey, clayey loam, sand clayey loam (Table1). Organic matter content was changed to very high to low. Some soil samples which were taken from fertilized fields had quite high values.

**Table 2: Boron content of plant samples**

| Soil and Plant sample point | Boron ppm | Soil and Plant sample point | Boron ppm |
|---|---|---|---|
| **2. Bozhuyuk-S.omer-Kutahya** | | **15. Hisarcık –Emet** | |
| Broad bean | 282.28** | Peach | 130.26** |
| Willow | 285.86 | Cabbage | 233.30** |
| Sunflower | 135.55 | Plum | 130.26** |
| Quince | 47.59 | Zucchini | 786.80** |
| Cherry | 75.41* | Wheat (germ) | 70.02** |
| Clover | 71.57 | Wheat (stalk) | 25.56** |
| Apple | 87.46** | Quince (leaf) | 86.79 |
| Sour Cherry | 49.33* | Oleaster (leaf) | 91.11 |
| Plum | 84.00** | Apple (leaf) | 288.14** |
| Almond | 37.93* | Sour cherry (leaf) | 99.45** |
| Bean | 369.69** | | |
| **3. Egrigoz-Emet-Kutahya** | | **17. Calcagıl-Emet** | |
| Celtis | 2184.58 | Plum (leaf) | 64.58** |
| Poplar Branch | 558.58** | Hazelnut (leaf) | 155.75 |
| Willow | 1817.42** | Grape vine (leaf) | 53.12* |
| Tomato | 675.30** | Apple (leaf) | 61.07** |
| Zucchini | 1593.27** | | |
| **4.Asagı yonca-Hisarcık-Kutahya** | | **18.Malı Farm-Emet** | |
| Pear | 76.59** | Wheat germ | 312.25** |
| Oleaster | 63.90 | Wheat stalk | 329.67* |
| Walnut | 533.76** | | |
| Tamarisk | 795.56 | | |
| **8.Dulkadir-Tavsanlı-Kutahya** | | **5.Igdeköy-Emet-Kutahya** | |
| Oleaster | 32.74 | Juniper ( fruit germ) | 28.89 |
| Wild Apple | 30.35* | Juniper (needle like leaves) | 33.07 |
| Walnut (leaves+fruit) | 104.23** | Juniper-2(fruit) | 25.82 |
| Apple (leaves+fruit) | 45.22* | Black mulberry | 288.51 |
| Plum | 36.23* | Mahalep (fruit) | 43.94 |
| Sour Cherry | 35.90* | | |
| Willow | 68.31 | | |
| **12.Kırgıl** | | **16.Doganlar-Emet** | |
| Wheat (stalk) | 36.28** | Grape vine (leaves) | 121.91** |
| Wheat (germ) | 30.67** | Peach (leaves) | 64.07** |
| Apple (leaves) | 98.50** | Almond (leaves) | 48.46* |
| Plum (leaves) | 80.76** | Pear ( leaves) | 78.00** |
| Peach (leaves) | 39.45* | Sour cherry (leaves) | 117.52** |
| | | Walnut (leaves) | 757.73** |

*:Normal boron content;**:Excess boron content

Boron can be held in soil via adsorption by soil or sediment. Clay content, organic matter content and pH of soils are the main factors play an important role for boron retention in soil (Goldberg et al. 1997., Chen et al. 2009., Arora and Chadal, 2010). As the result of boron determinations performed, it was found that the total boron content of the soil, sediment and waste was between 20-2000 ppm and their plant-available B content was between 0.01-744.39 ppm. Kabata-Pendias and Pendias (2001) stated that injuries occur on plant in high boron concentrations (1000 to 1500 ppm). It was observed similar symptoms and signs for plant samples.

High differences were found among the sediments in the soils regarding the amount of water-soluble boron that can be taken by plants. Plant available boron levels are substantially high in the areas that are the closest to the both boron enterprises. The boron content in the soils irrigated with the water of the stream near the enterprise X is high. The waste soil sample of Y- Enterprise also had the high boron content. It was observed that the boron content in the soils decreased as the distance of the soil from the enterprise increased. The water-soluble boron content values are also consistent with the total boron content (Table 2). In the present study, several plant samples were taken from the 10 points where the soil samples were taken and the boron content (ppm) of these samples were determined.

As it can be seen from the values presented in Table 2, the boron contents of the plant samples taken from the point numbers 2-3-

 

15-16 and point 17 were found to be higher when compared to the limit values given by Jones *et al.* (1991).

These sampling points are respectively the discharge channel of the Seyitömer thermal power plant-the point where the brook passing through the boron enterprise joins the Emet stream and the agricultural soils close to these points. Plant species ranked as Celtis>Willow>Zucchini>Tamarisk and Walnut (leaves) for high boron content in the leaves. Results indicated that Boron enterprise X releases more boron to the soils/environment than that of the Boron enterprise Y.

The values found at other sampling points (Mugla province) are within the sufficiency limits for B. In this case, it could be said that a significant amount of boron has accumulated in the areas close to the both boron enterprises and the level of accumulation decreases as the distance from this point increases. However, the boron accumulation in plants is still significantly high and this can be clearly seen in the plants taken from the areas irrigated with the water from the brook passing by the enterprises. When these limit values (Jones *et al.*1991) are taken as base, the boron of half of the plant samples in this study is at toxic levels. Under these circumstances, it is possible to observe boron-related health problems in the people or animals using these plants anyhow in the region. Boron-tolerant species such as *Puccinella frigida* which is tolerant to extremely high levels available boron in soil (Ramilla *et al* 2015) or local boron tolerant species can be used for boron phytoremediation to decrease the negative effect of boron in the environment.

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