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BORON IN GROUNDWATER OF THE ISLAND OF CYPRUS

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Boron can be found in high concentrations in the groundwater of the island of Cyprus, especially in the central part of the island. Boron in high concentrations is of major concern due to its toxicity to both animals and irrigated plants. The origin of the phenomenon is not very well understood and is usually explained as remains of seawater. This work quantifies the boron content through analytical techniques and provides more information on the levels found.

INTRODUCTION

Due to the water shortage and limited desalination capacity in the eastern part of the Mediterranean, groundwater is of primary importance for both irrigation and as drinking water. The presence of high concentrations of boron is undesirable and can be destructive for plantations such as lemons and oranges that are very sensitive to this element.

The same high concentrations were reported in parts of Italy (D'Avino and Spandre, 1995) and Greece, making this a common challenging problem to solve in the eastern Mediterranean region. Financially acceptable methods to remove this toxic element for irrigation purposes have not been successful.

Boron is an essential and basic element in all ecosystems as it is influential in metabolic processes of carbohydrates and amino acids (Saviozzi, 1991). Furthermore, boron is acting on a number on enzymes (Eaton, 1941 and Gupta, 1979). Other studies have also shown that boron is influential on the pollen tube growth (Russel ,1960) and in general in low concentrations is not only well tolerated, but also required for complete and healthy plant growth.

The toxic effects of boron have been shown on the reproductive system of laboratory animals (NTP, 1987). Peculiar development effects were also observed in rats and rabbits (Price, 1995).

BORON IN WATER

Concentrations above 1 ppm are considered toxic for most plants (Ayers and Westcot, 1985), while lemons and grapes, for example, cannot survive at all with this concentration. Table 1 shows some common agricultural crops and their tolerance to boron. Similarly, concentrations of boron above 1 ppm are considered toxic for both human and animal consumption (Price, 1995). The most recent European Guide number on the safe quantity of boron in potable water is 0.3 ppm, based on the results of boron toxicity on rats and rabbits (Heindel, 1992 and Price, 1995).

The negative effects of boron on crop production are very frequently confused with the effects of high salinity because of the similarity in the results of both elements.

Table 1. Representative Agricultural Crops and their Tolerance to Boron

Crop	Recommended B, PPM	Crop	Recommended B, PPM
Lemon	<0,35	Oranges	<0,75
Olive	<2,00	Fig	<2,00
Apple	<1,00	Peach	<0,50
Beans	<0.75	Cabbage	<2,00
Wheat	<0.75	Tomatoes	<2,00
Spinach	<5,00	Cotton	<6,00

THE STUDY AREA

The area under study is shown in Figure 1 and is made up of the major part of the island of Cyprus, with most emphasis given to the central part where the water shortage is more apparent yet vital for the island development, and where most of the population lives.

The area covered in this study is approximately 4000 km^2, with the plains and coastal areas having a greater problem of boron toxicity. The area is actually situated south of the Pentadactilus

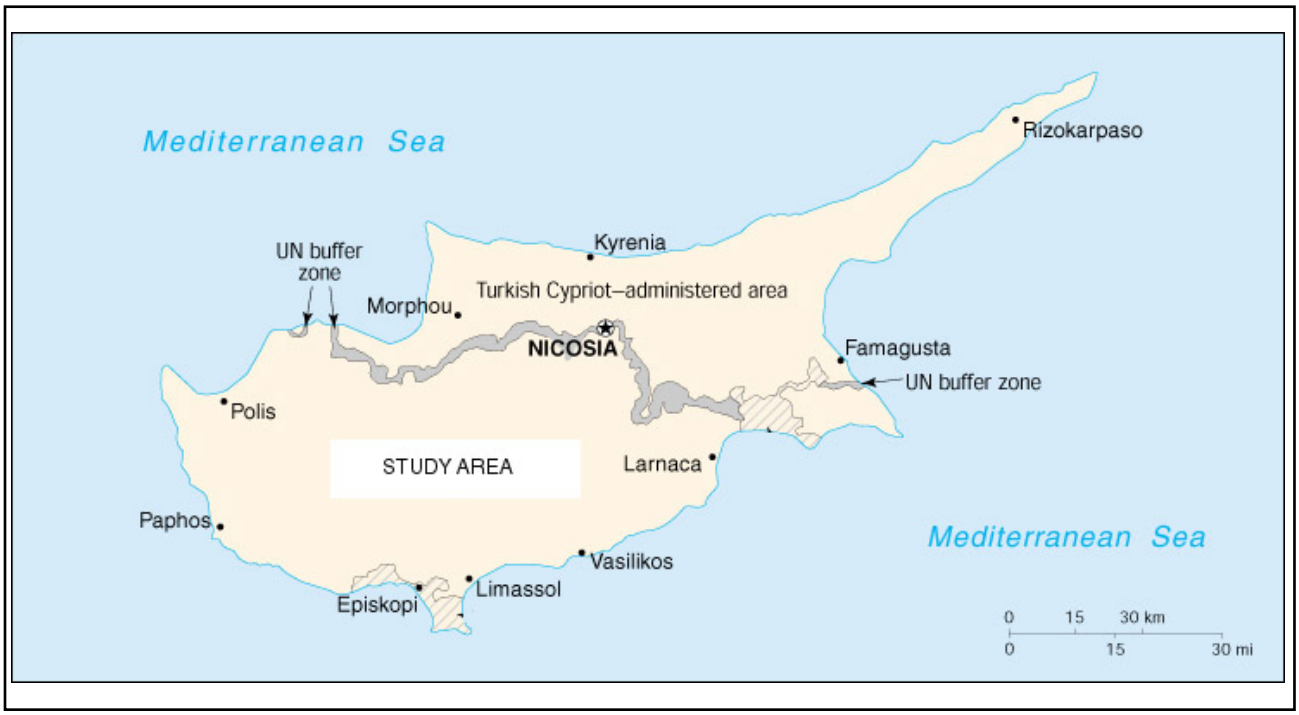

Figure 1. The island of Cyprus showing the study area.

Mountain and is surrounded by the Mediterranean Sea. Samples from all the accessible area on the island were analyzed in an effort to have representative results for the entire island. The island's main water supplies are situated in the central ridge of the Troodos mountains – where the boron content is minimal. Water supplies in the plains have high boron toxicity.

The west and southeast parts of the island are the main vegetable/crop production areas, and where most of the irrigation water is needed. These areas also face both the problem of boron toxicity and the problem of seawater intrusion along the coastline. Special attention was paid in the sampling process from these two areas to distinguish between the two factors.

RESULTS

A total of about 1200 water samples were selected for groundwater sources. The area under study and the map (Figure 2) of the boron concentration levels was constructed using a special gridding technique and curve smoothing.

Table 2 shows some of the characteristic results obtained from the analyses grouped as representative results in each geographical area. As can be seen, the values of boron concentration vary considerably with high concentrations in the plains and coastal areas and low ones in mountainous regions - above 1500 m elevation. A number of small areas show extremely high boron concentrations to the degree that only the most tolerable plants could hardly be watered with (Nata and Polemi with 12 and 9 ppm respectively). The water is useless for human consumption.

From the observed distribution of boron concentrations it is clear that there are three main areas which have a serious problem with groundwater toxicity. These areas appear to have little relation with the rest of the island groundwater. The boron concentration in the groundwater in these areas is so high that is not suitable for humans or any crop production, making the life of the few locals hard and in absolute need of an alternate water supply.

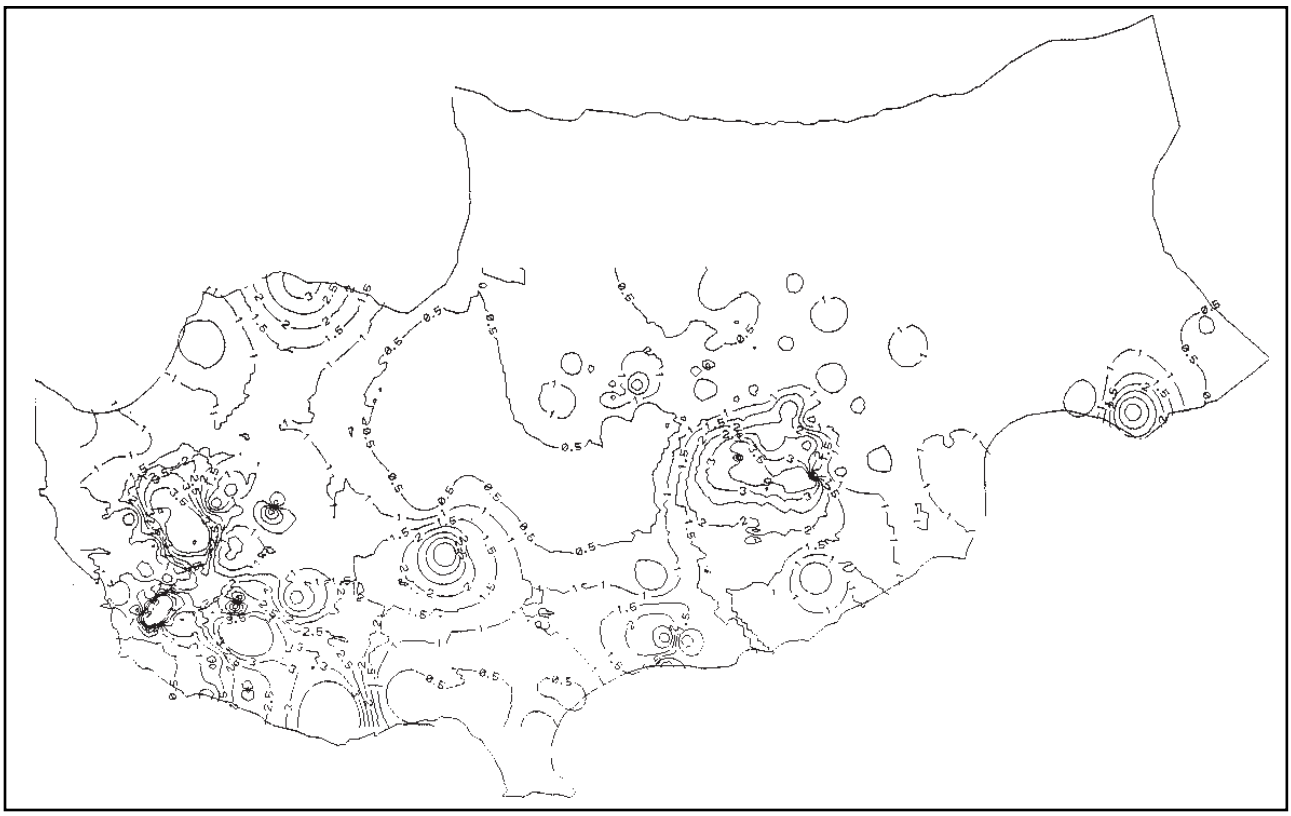

Figure 2. The distribution of boron over the study area, based on 1200 sampling points.

Table 2. Representative Samples of Boron Concentration

Place	Concentration PPM	Place	Concentration PPM
Nicosia Area		**Limassol Area**	
Nicosia	0.62	Paramali	0.17
Kyperounta	0.09	Erimi	0.36
Sia	6.20	Limassol -town	0.27
Ag. Timithias	0.33	Pera-Pedi	4.20
Lythrodonatas	5.64	Pareclisia	3.27
Mathiatis	2.30	Episcopi	0.22
Mitsero	0.66	Fasouri	0.33
Tseri	0.23	Moni	0.23
Troodos	0.05	Kelaki	0.32
Larnaca Area		**Paphos Area**	
Pyrga	0.13	Nata	12.00
Kiti	0.59	Eledio	4.00
Ag. Theodoros	2.70	Pissouri	5.60
Kornos	5.80	Achelia	0.50
Larnaca	1.48	Kanaviou	1.75
Ormidia	0.36	Mesa Chorio	6.80
Kato Dris	0.17	Polis	1.60
Lefkara	3.14	Polemi	0.30
Aliki	2.40	Kouklia	3.60
Athienou	1.20	Stroumpi	0.20

CONCLUDING REMARKS

The origin of the boron in groundwater is usually assumed to be the seawater – due to the origin of the island, which was formed as a result of the compression of the African and the Asian plates, and seawater intrusion into the coastal areas. This explanation however cannot justify the extremely high values of 12 ppm found in certain areas.

Another possible origin is pollution from wastewaters. This is possible, but due to the absence of any industry in these areas, along with the measures of the Cyprus government for many years now to reject any import of products having boron in excess of 20 ppm, industry is probably not the cause of this problem. In areas where wastes are deposited the concentrations do not appear to be high. Concentrations do not appear to be reducing with time.

The suggestion that the boron source is a deeper water that feeds the groundwater with circulating boron rich fluids (D'Avino and Spandre, 1995) was never examined, but it does seem unlikely due to the large variation of the depth where the high boron concentrations are found.

Regardless of the above explanations given by other authors, the author would like to suggest the hypothesis, hoping that would be a starting point for future work, that most of the boron is actually due to boron-rich rocks that are in the process of eroding.

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