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Research Article

Evaluation of Boron Concentration in Akhüyük (Ereğli) Geothermal Source in terms of Medical Geology

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Abstract

Some of the thermal waters are used for drinking, some in bath cures and some in both. In addition to the elements that will benefit the living organisms of the thermal waters, the negative consequences of the toxic elements above the limit values are inevitable. The historical and scientific structure of medicine and geology has created a common field of work related to humanitarian activities and problems that arise naturally with modernization. This requirement led to the emergence of medical geology. The study area is in Eregli - Bor Neogene basin. In the scope of this study, the boron concentration of the water was determined in the geothermal area at the Eregli District. In the scope of this study, the boron concentration of the water in the geothermal area at the Eregli District was determined. The results of the analysis of the water found in the study area by the General Directorate of Mining Inspection, results of the analysis made by Ereğli Municipality, and water sample results from this study were evaluated. The effect of boron concentration on living things has been interpreted in terms of Turkish standards and the maximum boron concentration values recommended by the World Health Organization.

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INTRODUCTION

Boron is the element with more than one hundred minerals on the earth that can be used for different purposes [1]. Boron is the first element in the 3A group with atomic number 5 and is indicated by "B" on the periodic table [2]. For the first time in the world, the elemental boron was found in 1808 by Thenard, Gay-Lussac and Davy at the same time. Boron compounds with long history are widely used in a wide range of applications such as agriculture, health, energy, computer, cosmetics, cleaning, whitening, ceramics, glass, metallurgy, nuclear and aircraft industry. Thus, a very wide range of boron products come into our daily life [3]. Boron element, which has a very large reserve within the borders of our country, is very important in terms of health sciences as well as production-based real sectors such as industry, technology and agriculture. The historical and scientific structure of medicine and geology has created a common area of work related to the problems arising from the products of human and natural processes that emerge along with the modernization. This study was evaluated in terms of medical geology which investigates the relationship between the elements, minerals, rocks, soil, water emerged as the natural results of geological environments and these processes and environmental health, the use of boron compounds in the treatment of diseases is thought to become as important as industry and technology in the following years. Boron compounds are also used in the medical field. Uses of boron compounds in medicine are; the treatment of osteoporosis and rheumatoid arthritis, Boron Neutron Capture Therapy (BNCT) used to treat brain tumors, burn treatments, wound healing, antiseptic lens solutions, ointments, mouthwashes and eye drops. Along with all these, the drug named "Bortezomib" which contains boron is accepted by the Food and Drug Administration (FDA) for the treatment of multiple myeloma. [4]. In this study, the results of chemical analyzes on the water samples taken from Akhüyük geothermal source in Ereğli district of Konya province were evaluated. Some of the hot spring waters which emerge from geothermal sources is used for drinking, some for bath cures and some for both. In addition to providing benefits to the living organisms, the excess of toxic elements found in thermal waters above the limit values can cause harm. People take boron compounds into their bodies by means of breathing, contact and digestion. Studies conducted on animals, adults and young children have shown that long-term contacts with boron damage skin [5]. According to the chemical analysis of the water samples

taken from the geothermal source from the study area, the boron value was compared with the previous years' studies and its effect on the body was investigated.

MATERIAL AND METHOD

For this study, field study was started after evaluation of previous studies conducted in the region. The region was examined geologically and the boundaries of the existing formations in the study area were checked. The study area was examined in detail in terms of whether there is another geothermal source (Figure 1). Ridge or conical formations caused by old hot water outlets were detected in the field. There are two geothermal wells in the field and KEA-2 well where water samples are not available. For this reason, a water sample was taken from the KEA-1. Both the sample of this study and the water sample taken by Ereğli Municipality were taken by a commission established by the provincial public health directorate during the spring. In the previous study, the water sample was taken in the fall period. In this study, water samples were taken into special containers with a sampling capacity of 500 and 1000 ml, which were gamma sterile, with a 50 mm wide mouth, and a leak-proof seal inside to prevent leakage. The water samples were taken into the cooled carrying bags and delivered to the laboratory. Water samples were analyzed with ICP-OES model in Envirolab Measurement and Analysis Services (ind.trade.co.ltd.) and inductively coupled plasma-optical emission spectrometry (PerkinElmer ICP - OES) was performed by three replications with EPA 200.7 method. The results of the analysis in this study and the results of the analysis found in previous studies were compared and are subjected to evaluation in terms of Turkey and World drinking and using water standards. For the geological evaluation of the region, the physical properties of the travertine in the area, formation boundary relations and the physical properties of the alluvium unit were investigated in detail. The thickness of the travertine unit has been determined by the mirrors in the open travertine quarry which is already produced in the field and by the drilling of the borehole made from this quarry.

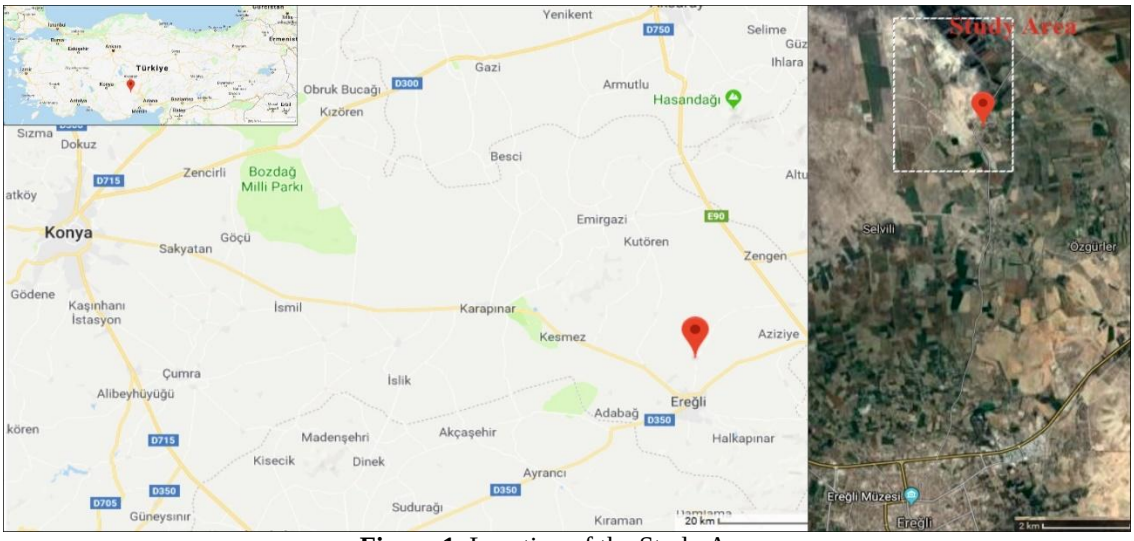

Figure 1: Location of the Study Area

EFFECTS OF BORON ON HEALTH

In terms of boron compounds, research and development has been made in our country in previous years mostly for industry and technology. The acceptance of boron mineral as an essential supplement for humans is towards the middle of 1980. According to the previous studies the amount of boron required to be taken for healthy and balanced diet is 1-13 mg / day which is sufficient and necessary. The human body is tolerant to the amount of boron at a level of 0.4 mg / kg body weight and the minimum amount of boron coming from food should be 1.2 mg. [5-6]. It was stated that males take more boron than females, and boron uptake increases as age progresses. Boron amount to be taken in daily nutrition varies according to age groups; 548 µg in 0 - 2 year old children, 594 µg in 14 - 16 age girls, 853 µg in boys, 690 µg in women aged 25 - 30, 890 µg in men, 754 µg in 60-65 years old females and 883 µg in males. The amount of boron should be taken from various foods per day varies between 600-1200 µg [7-8]. In order to understand the importance of boron in terms of bone health, 12 women received a diet with a low boron ratio (0.25 mg / day) during the postmenopausal period of 119 days and in addition, a supplementary capsule containing 3 mg boron was added to the diet for 28 days. As a result of the tests performed at the end of the study, it was found that the calcium content in the urine decreased by 44% with the support of the boron element and it was concluded that the boron could prevent osteoporosis in the postmenopausal period [9]. In a different study conducted on men, calcium excretion in urine decreased whereas calcium uptake in bone increased by 17% in males supplemented with 10 mg boron

every day over a 4-week period [10]. Boron has an important function in the metabolism of calcium and magnesium, which is the basic need for joint movements and bones. In addition to activation of calcium and Vitamin D, it is stated that it is effective in protecting bone tissue and preventing demineralization, and strengthening immunity and hormonal system [11,12,13]. It has been argued that boron can be effective in human brain functions and mental performance, and when people are receiving low amounts of boron through nutrition, deterioration in hand-eye coordination, decrease in attention and perception, and significant deterioration in short and long term memory have been observed [14]. It is known that the amount of blood hemoglobin increases significantly when supplemented with boron [15]. There are some findings suggesting that boron has a protective effect against some types of cancer. In the areas where boron minerals are present, it is determined that the values of prostate cancer decreased in the region with the introduction of minerals into the body and nutrient content, and the boron can be very effective in the prevention of prostate cancer [16,17]. It has been determined that the risk of prostate cancer, lung cancer and abnormal cervical cytopathology, which are common type of cancer diseases in humans, decrease due to the increase in boron intake. In a study conducted on 763 women with lung cancer and a control group of 853 people, it was observed that the risk decreased with the increase of boron intake [18,19]. According to the studies, it can be stated that boron is effective against prostate cancer [15,16,17,20]. In another study investigating the effect of boron on prostate cancer, 8720 healthy individuals were compared in 95 cases and it was found that low amount of boron intake increased the risk of prostate cancer [20]. Critical threshold values vary in different countries and regions of the world. In the study conducted by EFSA (European Food Safety Authority), it is known that the amount of boron contained in drinking water is 0.2-0.6 mg / day [21]. The different countries of the world, especially the US and European Union countries, have announced various studies and opinions on the amount of boron daily intake requirement. While the maximum acceptable limit for adults set by the United States Medicine and Food and Nutrition is 20 mg / day, World Health Organization announced the amount as 0.4 mg per 1 kg of body weight. On the other hand, the European Union determined the limit of 10 mg / day as the recommended maximum daily intake of boron. The EFSA 2013 panel announced that the daily maximum level of boron intake should be 0.16 mg kg / day [5,22,23]. The lowest lethal dose of boric acid is 640 mg / kg when entered into the

body via the oral route, 8600 mg / kg when it penetrates through the skin and 29 mg / kg when it is injected. If more than 500 mg of boron is taken signs of poisining observed in a healthy person are; nausea, vomiting, head and abdominal pain, diarrhea, muscle contractions, shock, fatigue, digestion and central nervous system disorders, disruption of the functioning of the glands, and skin lesions. In children, toxic effects of boron causes brain membrane destruction such as referral and coma. The characteristic sign of boron poisoning is the pink color seen at the fingertip which is the most distinctive and distinguishing indication of boron poisoning [24,25]. The way the boron is removed from the body is the same in humans and animals. The tolerable amount of boron entering the body through nutrients, breathing, etc. is excreted by 90-95% directly from the body through the urinary tract without any accumulation. Boron accumulates only in organs such as bone, hair, nail, spleen and liver [5,26,27]. Drinking water with high boron minerals content causes disturbances in the digestive system and may cause serious problems such as liver growth and swelling [28]. According to the studies conducted in our country and in the world besides its possitive effects in treatment, overdose exposure of boron may cause serious health problems. In general, the therapeutic effects of boron minerals are; regulate steroid hormone metabolism, help the bones to grow and strengthen, antioxidant effects, help the immune system to strengthen,short the healing process, regulate energy metabolism, play a protective role against different types of cancer and reduce the possibility of their occurrence, increase brain function and performance, treat blood cancer and slow down excess weight gain [29].

AKHÜYÜK GEOTHERMAL FIELD

The geothermal area within the boundaries of the Akhüyük neighborhood of Ereğli district of Konya province is 158 km to Konya and 12 km to Ereğli. In the research area where continental climate is dominant, the most rainy season is spring and the driest season is summer. The vegetation also consists of steppe species depending on these climatic conditions. Tree and shrub formations on the field is less than the dominant plant species in herb formation [30]. The site was first discovered by the General Directorate of Mineral Research and Exploration. There are two geothermal wells in the field.

Regional Geology

Many researchers have performed geological studies related to the study area and its surroundings [31,32,33,34,35]. In this study the regional geology was evaluated by using the previous studies conducted by the researchers (Fig. 2).

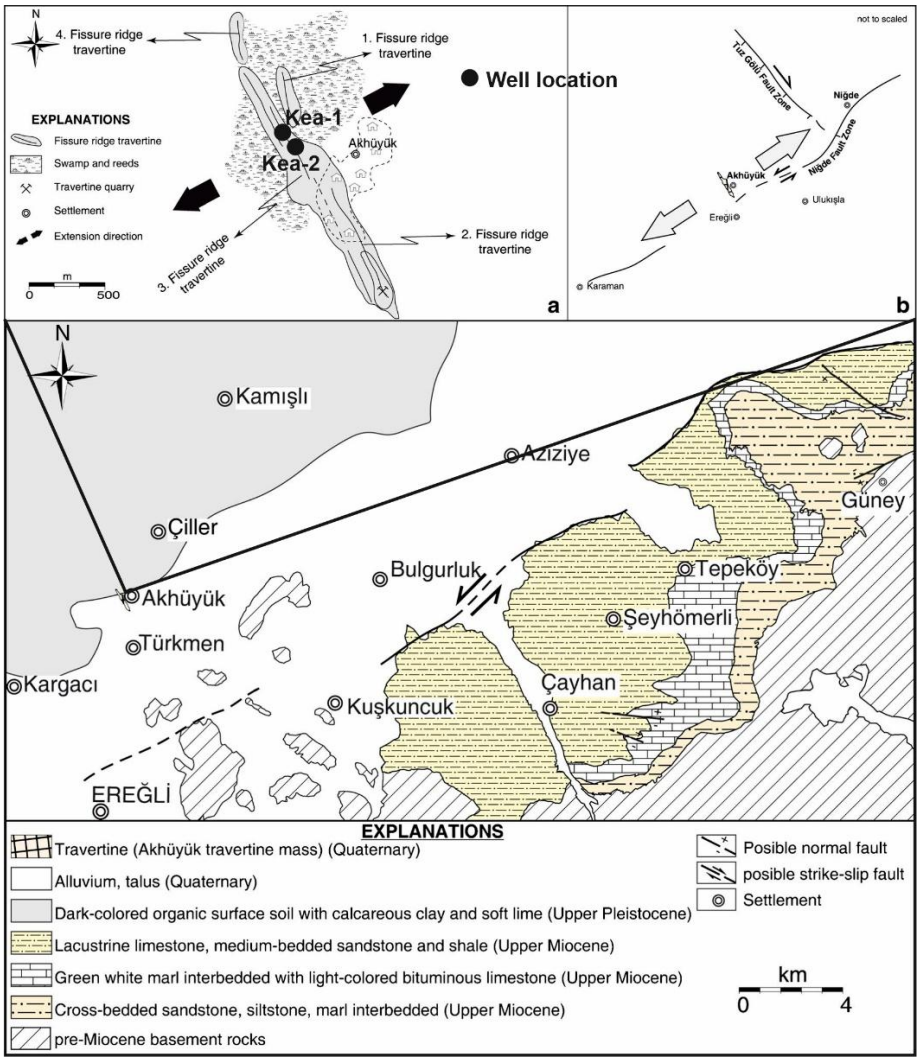

Figure 2. Regional geology and location map [36]

The study area lies within the Ereğli - Bor Neogene basin and consists of the Lower Paleozoic Nigde Group rocks. This unit was cut by Upper Cretaceous Sineksizyle Metagabros and Üçkapılı Granodiyrite. Ulukışla - Çamardı group consists of limestone blocks, Paleocene-Eocene volcanics, siltstone, sandstone and conglomerate of volcanic rocks. This unit was cut by Köyderesitepe trachytes. The Upper Paleocene-Eocene aged Başmakçı limestone, which is a reactive nummylitic limestone, overlies the Serenkaya formation. All these units were cut by Cehritepe syenite (Lower Eocene). This unit is overlain by Karatepe limestone. The volcanic

effect ended in the Central Lutetian and the South formation consisting of gray-beige colored siltstones began to precipitate. Due to the orogenic movements in Upper Lutetian, angular unconformity occurs between these rocks and the overlying units. As a result of the shallow marine - lagoon environment of the basin which began to occur in the Upper Eocene - Oligocene, an evaporitic deposit, Zeyvegediği anhydrite, was formed. Zeyvegediği anhydrite begins with light colored and stratified anhydride at the bottom and then proceeds to upper levels with brownish, thin stratified sandstone-limestone and green marl. It consists of white colored stratified anhydrite and brownish clayey gypsum to upper levels. The lacustrine units were precipitated by sedimentation after this evaporitic sequence. The abundant presence of living organisms in this period has caused the abundance of organic material to be transported to the lake setting. Transported organic materials formed bituminous shales in an oxygen-free environment where the lake was deepened. This unit, which is called Katrandede Tepe formation, begins with green, white colored marls, followed by clayey limestone and marl. This unit contains bituminous shale levels in between. These bituminous shale levels continue alternately with evaporit units. Above this unit, Beştepeler formation consisting of the clayey limestones and white, gray, dark gray, dirty white hard thin and smooth layers and conglomerate and sandstone-like clastic units formed due to re-shallower formation of the lake exists. To the north of the basin in the Tuz Gölü basin, volcanic activity from Upper Miocene-Pliocene to Quaternary has taken place. These activities affected the basin in terms of salinity. In the Upper Miocene-Pliocene, Melendiz and Hasandağı volcanism, which are formed on the large tectonic lines, form the elevations in the plain. The lavas of the Ojit-Andesite, Pyroxene-Andesite species belonging to the Melendiz volcanics were followed by the Hasan Mountain volcanism of the Andesite-Basalt type in Quaternary and finally the alkaline type volcanism in the plain [31,32,33,34].

Geology of the Study Area

The study area lies within the Ereğli - Bor Neogene basin. The definition and border relations of the formations were examined in detail in the field studies with the help of previous studies. Quaternary alluvial and travertine units were observed in the area.

Travertine

The unit developed due to the fossil geothermal outlet is a long slender zone which is depending on the topography 2.2 km long and has a thickness ranging between 13 and 16 meters and is approximately 120 meters wide, with Akhüyük village in the middle. Travertines have dirty white, cream and white colored smooth layers and are located between black and green colored layers. From the drilling of the travertine quarry located in the study area and the visible mirrors observed in the plant, the thickness of the travertine was determined. In the study area, back shaped travertine is generally observed but very little cone or dam shaped ones. Travertines on the field were precipitated as a result of loss of CO_2 gas in fluids rising up through the opening cracks. The smell of H_2S is felt and the current sulfur formations were observed.

Alluvium

Alluvium covering a very large area in the study region; consists of untied clay, silt, sand and gravel which unconformably covers other older units.

Evaluation of Chemical Analysis

In this study, the geology of Konya Ereğli Akhüyük geothermal field and its close vicinity were investigated and the two wells drilled in the field for geothermal purposes were examined in May 2018. Water samples were taken from one of these wells (KEA-1) for chemical analysis. The sample was placed in special plastic sterile container and brought to Envirolab measurement and analysis services (ind.trade.co.ltd.).. Boron concentration was found to be 174 mg / lt. In previous studies, boron concentration was measured in water samples taken from that geothermal field. In 2012, [31] stated that, according to the chemical analysis of water samples taken, boron concentration is 251 mg / l in KEA-1 well and 254 mg / lt in KEA-2 well. As a result of the chemical analysis of the study carried out in the KEA - 1 well of the Ereğli municipality in 2017, the amount of boric acid found is 2118,41 mg / lt. For many years boron has not been considered as a toxic element. In 1958, 1963 and 1971, the International Standards on Drinking Water prepared by the World Health Organization have not been mentioned about boron.

Table 1. Boron concentration measured in water samples taken from wells

	MTA	Ereğli municipality(boric acid)	This Study
KEA-1	251 mg/lt	2118.41 mg/lt	174 mg/lt
KEA-2	254 mg/lt		

It was accepted that boron did not have any toxicological effect at the limit values published by the World Health Organization for drinking water in 1958-63 and 1973. In 1984, for the first time in this year's published articles, the boron element was mentioned and it was explained that there was no need for a study to reduce the boron value in drinking water. In 1993, for the first time in laboratory studies, harmful effects on animals were understood and the boron upper limit value in drinking water was stated as 0.3 mg / l. In 1998, it was increased to 0.5 mg / lt. Then, the maximum accepted upper limit value of the boron was increased to 2.4 mg / lt by taking into consideration the daily intake within limit values [37,38]. Table 2 shows the permissible upper limit concentrations of boron in drinking water of different countries. As it is understood from the table, many countries do not adhere to the recommendations of the World Health Organization. Saudi Arabia and Israel are the only countries that comply with these decisions. In the US, there is no regulation on the amount of boron concentration in drinking water, while Canada and Australia have set limits above the recommended upper limit. The first of two reasons for higher limit value is; there is not enough concrete information to prove its negative effects on human. Secondly, boron removal methods from waters are difficult and it is costly to reduce the boron concentration below standards [38]. According to Water Intended for Human Consumption Regulation published in Turkey, the upper limit of boron concentration which can be permitted was identified as 1 mg / L.

Table : 2 Permitted drinking water concentration in different regions of the World [37]

Regions	**Max Boron Concentration mg / lt**
Saudi Arabia	0.5
United States of America	-
Minnesota	0.6
New Hampshire	0.63
Florida	0.63
Maine	0.63

Wisconsin	0.9
European Union	1
South Korea	1
Japan	0.2
New Zeland	1.4
Israel	0.5
Australia	4
Canada	5
Turkey	1
WHO's recommended value	0.5

DISCUSSIONS

Boron element is frequently seen in scientific studies related to industry, food and agriculture, cleaning and health services. In recent years, studies of health sciences showed that daily intake of boron is different [5,6,7,8] in diets of children, young people, adults and elderly people depending on the gender. In a study conducted on postmenopausal women in terms of bone health, it was found that the amount of calcium in urine decreased by 44% at the end of the study with boron supplementation for 119 days [9]. In another study conducted on males, it was determined that calcium excretion in urine decreased 17% with the increase of daily boron intake [10]. Low levels of boron uptake have led to temporary memory losses in human brain functions and mental performance [14]. It was stated that Boron has preventive and protective effects in some types of cancer [15,16,17,18,19,20]. According to all these studies, boron element, used in proper amounts, has protective and preventive effects in terms of health related issues, while it is known to have toxicological effects in living organisms at high doses [5,24,27,28]. The present study evaluated the boron concentration of the sample from geothermal sources according to the chemical analysis performed and it was found that the limit values is above the limit values of standards set by Turkey and the World Health Organisation drinking water guidelines [38] .

CONCLUSIONS

In this study, analysis results of water sample collected were evaluated according to Turkey and the World drinking water standards. According to the results obtained in this study; it was determined that boron concentration was above the drinking and potable water standards. When it is evaluated in terms of medical geology, according to the studies mentioned above related to health and food; it is

known that boron contributes to bone development, decreases the risk of cancer, increases mental performance and can benefit in human in many ways [15,16,17,18,19,20]. A total amount taken more than 500 mg per day may cause toxicity symptoms such as nausea, vomiting, headache, abdominal pain, diarrhea, muscle contraction, shock, weakness, digestive and central nervous system irregularities, impaired functioning of the glands and skin lesions as reported in different studies. The effect of boron concentration in thermal waters on people who are exposed to it in spa cure applications should be investigated in detail.

Thanks

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