The Use of Wetlands in Boron (B) Remediation in Turkey

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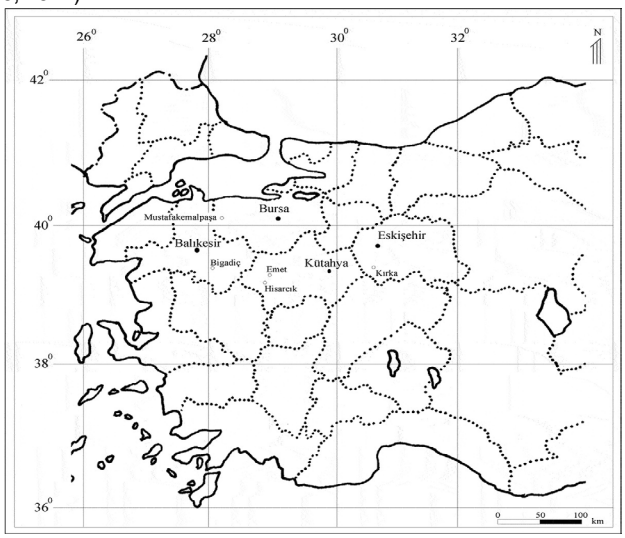
Boron (B) contamination of water sources from mining and other activities have aroused more and more global attention (Wolska and Bryjak, 2013). The known boron (B) mine reserves all over the world are mainly located in Turkey, the United States, China and South America. On the other hand, Turkey contains approximately 70% of total B reserves with 803 million tons, and has supplied the majority of the B used in the world, so that the potential for the contamination of freshwater resources there is high (Turker et al., 2013a). The B reserves in Turkey occur in Western Anatolia, main reserves are speared in Mustafakemalpaşa, Bigadiç (Balıkesir), Bursa, Hisarcık, Emet (Kütahya), dominated by the Kırka (Eskişehir) borax (tincal, $Na_2B_4O_7$) deposit. Boron mining activities in Western Anatolia reach their maximum level, and, thus, around 45000 km square of ecosystem has a large potential for elevated point or non-point of B pollution, which can leak and diffuse into the receiving water body (Türker et al., 2013a; Türker et al., 2013b; Böcük et al., 2013).

FIGURE 1.
Boron (B) mine reserve area in Turkey (with a permission by Böcük and Türe, 2014)



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To provide an ecological context, wetland projects supported by the Scientific and Technological Research Council of Turkey and Scientific Research Funds of Anadolu University to understand remediation of boron mining areas with wetlands. The usage of wetland systems for B wastewater remediation is a relatively new technology and created wetlands have never before been specifically designed and used for the prevention and control of boron pollution to protect surrounding natural areas. Therefore, our idea is to remediate boron pollution using wetlands positioning in the landscape to intercept boron before it can enter into adjacent natural water bodies and wetlands. The remediation program was performed from 2010 to 2015 at largest Borax mine reserve area (39° 17' N, 30° 30' E) in all over the world (Kırka country - Eskişehir in Turkey) under natural climatic conditions. Ten types of wetland systems were established using different vegetation structure and plant combination in order to test wetland boron remediation efficiency in the boron remedial program. The wetland systems consisted of a chamber 2 m in length, 1m in width, 0.6 m in depth (water depth is 0.4 m) with a surface area 2 m^2, and employed gravity feed using 1.5°.

A doctorate thesis study conducted by Böcük (2010) researched the natural plant diversity of all boron reserve areas in Turkey as well as the status of their adjacent environments, their tolerance to boron and the potential phytoremediation capacities of some boron-tolerant plants. Following Böcük's work, we chose four native local macrophyte species, which can grow in boron rich environment, to test for the remediation program: *Typha latifolia* L., *Typha angustifolia* L. (Typhaceae), *Phragmites australis* (Cav.) Trin. ex Steud. (Poaceae) and *Juncus gerardii* Loisel. subsp. *gerardii* (Juncaceae). These sepcies were collected from natural wetlands surrounding the Kırka B mine reserve area. After collecting healthy rhizomes of the plants were immediately transported into the wetlands.

FIGURE 2.
The largest Borax mine reserve area in the world is in Kırka county – near Eskişehir, Turkey)

FIGURE 3.
Volunteers collected the plants' rhizomes from wetlands surrounding the Kırka B mine reserve area and transported the plants into the wetland systems.

In this remedial program, the ability of wetlands for the preventions and controlling of boron pollution under the actual environmental conditions was assessed and tested within the largest boron reserve area all over the world. Furthermore, crucial information about optimum plant selection investigated for B phytoremediation to simulate the actual a wetland system as closely as possible. In this way, the growth characteristics and boron phytoremediation capability were screened to determine if these species were effective in removing boron from the water. This research is critical for developing approaches to purify contaminated wastewater and to address a critical pollution problem in mining areas.

Our study found that the presence of plants in these created wetlands had a positive effect on water quality of the wastewater that flows into wetland systems. These plants take up boron directly and store it in their tissues. This process leads to higher levels of sorption or adsorption around the rhizopshere and sediment. Because our work may also be of interest to researchers, we have written several articles.

Another major aim in this remedial project is to train masters and PhD students in this remediation technique. Berkan Aras who is the volunteer student in the B remedial program emphasized that "I learned how a wetland systems remediate B in the wastewater before the B can reach the receiving water body such as surface water source. I also gained an understanding of the scientific method and used crucial elements of the method in the B remediation process". Master students Nurcan Gür and Ömer Fatih Gündüz concluded that "this remediation project offered much potential for testing a wetland system for B remediation.

As master students; we learned to evaluate this innovative method in field conditions and learned to work in collaborative teams". Overall, our work has provided valuable research and student training in the area of boron mine reclamation and wastewater treatment. ■

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FIGURE 4.
Wetland systems for the B remedial program in the Kırka B mine reserve area

FIGURE 5.
Researchers and students measured plant height and determined B toxicity symptoms during the remediation study.