Tracing the relative distribution of arsenic species in groundwater and its association with soil arsenic levels in the Simav Graben area, Turkey

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SUMMARY: A comprehensive hydrogeochemical assessment was conducted in the Simav Plain, Turkey where major health concerns were reported and elevated arsenic levels were previously found. Boreholes drilled in the plain were used to take core samples from the alluvial aquifer from which most groundwater was extracted. The results of core analyses revealed several orders of magnitude higher values than world average. Groundwater samples were later collected from these boreholes and analyzed for arsenic and its species as well as other related hydrochemical parameters. The results of groundwater quality assessment revealed that the groundwater in the plain was enriched with arsenic that exceed 1 mg/L level and was mostly under reducing conditions. The dominant arsenic specie in groundwater was arsenite in more than 70% of all samples.

1 INTRODUCTION

Arsenic (As) is a proven carcinogen that causes internal organ and skin cancers when it enters the body through oral or dermal route. Throughout the world, many countries including Bangladesh, Taiwan, India, Chile, Argentina and USA are experiencing geogenic arsenic problems in groundwaters (Bhattacharya *et al.*, 2012). Similar As-related problems have emerged in Turkey in recent years and difficulties in drinking water supply were experienced in some residential areas (Gündüz *et al.*, 2010a, Baba & Sözbilir, 2012). The Simav Plain is one of those areas with above standard As concentrations in surface and subsurface waters (Gündüz *et al.*, 2010b). This study presents the results of the hydrogeochemical assessments of subsurface waters in the region as well as the sources of As and its dominant species.

2 THE STUDY AREA

The Simav Graben Area is located in west-central Anatolia and is a semi-closed basin that contained the Simav Lake (Fig. 1) which was drained in the 1960s and was converted to agricultural land. It is a E–W trending Pliocene to Quaternary asymmetric depression that was developed on the older NE–SW trending Miocene basins in Western Anatolia (Seyitoğlu, 1997). The graben is bounded from the south by an active oblique-slip normal Simav fault. The graben fill is composed of semi-lithified boulder conglomerate and sandstone.

The Simav geothermal field that is situated to the north of the Simav district center has three geothermal outflows (Fig. 1) with reservoir temperatures reaching as high as 170 °C. (Gündüz *et al*, 2010b).

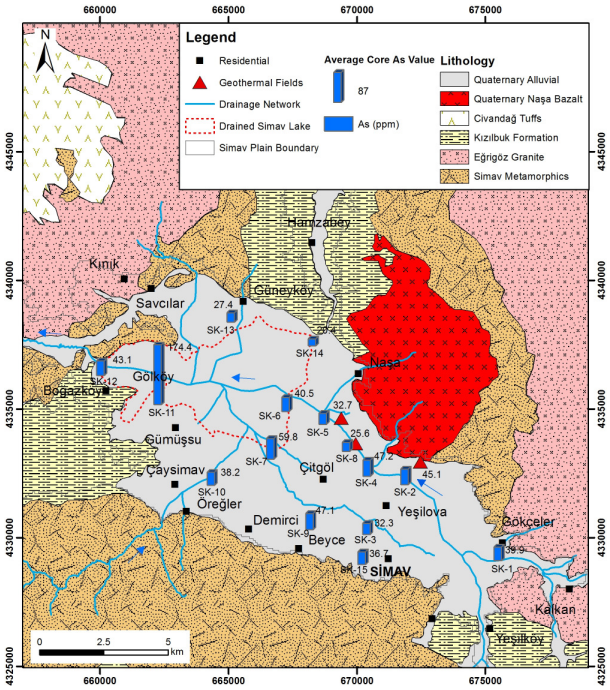

Figure 1: Geology of the study area and distribution of core As

3 METHODS

Research boreholes were drilled in 21 locations to a total depth of 846 m and 157 core samples were taken to determine the depth-integrated geochemical status of the plain. Elemental analysis of these core samples were conducted by acid extraction followed by detection using ICP-MS. The boreholes were then converted to groundwater monitoring wells by locating filters at elevations that correspond to high core arsenic levels. Samples were later collected from these 21 subsurface water monitoring boreholes as well as 7 other wells that were previously drilled in the area. In addition, samples were also taken from 3 geothermal waters in three different sampling periods during the study. All water sam-

ples were then analyzed for total arsenic, arsenite, arsenate and organic arsenic species (DMA, MMA) with ICP-MS and LC-ICP-MS tandem techniques.

4 RESULTS AND DISCUSSIONS

Based on previous studies, the metamorphic rocks of the region has strong iron and sulfide oxidation due to hydrothermal alteration and arsenic is typically observed in sulfide oxide sediments transported from these rocks that create the Quaternary alluvium sediments (Gündüz et al, 2010b). A comprehensive study was conducted on the sediments and groundwaters of the plain to determine the vertical layering of arsenic containing sediments. Geochemical analysis conducted in 21 boreholes revealed that the alluvial sediments of the plain had arsenic levels that are 2 to 3 orders of magnitude higher than world average value. The 157 core samples taken from 5-18 different depths had maximum, minimum and average arsenic values of 833.9 ppm, 7.1 ppm and 48.99 ppm, respectively, which are clearly higher than the world average value of 1.5 ppm. Spatial distribution of core sample arsenic values are given in Figure 1.

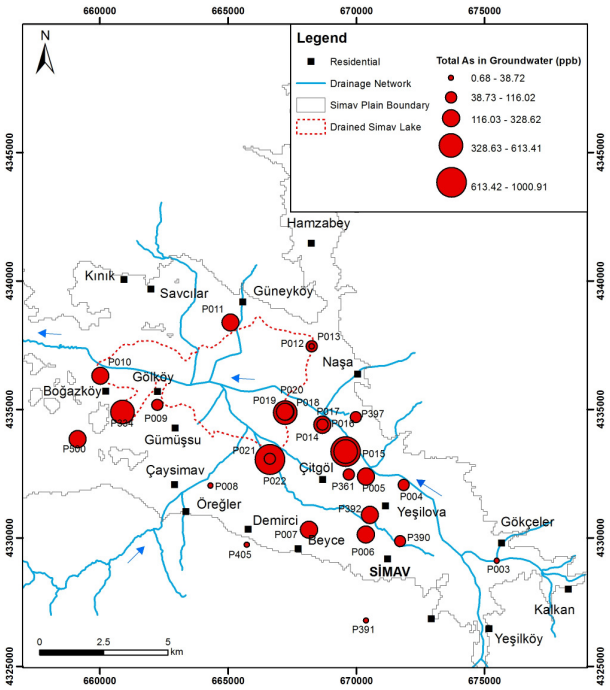

Figure 2: Total As in groundwater in Simav Plain

On the other hand, total As levels in groundwater samples ranged from 0.48 to 1000.9 ppb with an average value of 227.8 ppb (Fig. 2). Thus, the majority of the wells sampled had total arsenic concentrations that are 2-3 orders of magnitude higher than the standard value of 10 ppb. In addition, speciation studies conducted on these samples also showed that dominant arsenic specie in 20 of 28 wells was the more toxic As(III) with values ranging from 0.3 to 909 ppb and an average value of 183.4 ppb. As(V) was the second most dominant specie, and DMA and MMA species were below detection limits (Fig. 3).

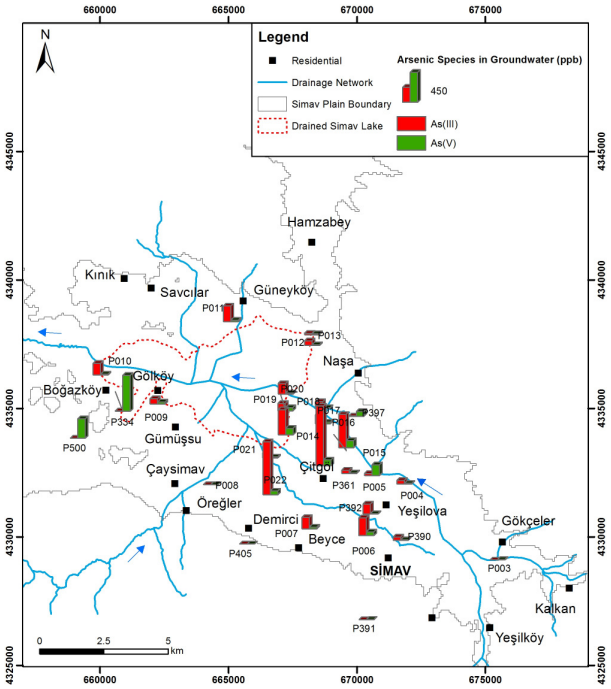

Figure 3: Dominance of As species in Simav Plain

5 CONCLUSIONS

Total arsenic values were found to be several orders of magnitude higher than the standard value of 10 ppb in Simav Plain. This result is strongly supported by the presence of elevated values of arsenic in core samples. As groundwater in the plain was mostly under reducing conditions arsenite was the dominant specie and reached to about 1 mg/L, indicating significant arsenic pollution in the region. These results indicate an eminent risk for direct human consumption of groundwater and further necessitate the use of arsenic removal technologies for all residential areas supplying their drinking water from the plain.

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