



Investigation of the radiation risk to the inhabitants in the region close to the hydrothermal alteration site, Gümüşhane/Turkey

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Abstract

Today, there is sensitivity in the society about human-induced environmental risks and this sensitivity is shown in many things we eat, drink and wear. This sensitivity has become so prioritized that in some cases the environmental risks of natural origin are in the shadow. In some cases, environmental impacts of natural origin can be more dangerous even if people are not aware of it. These include carcinogenic minerals, heavy metal contamination and / or natural radiation in the environments where people live. This study is aimed at evaluating the radiation exposure risks of inhabitants in the site close to hydrothermally altered area, Demirören, Gümüşhane-Turkey. For this purpose, forty-nine soil samples were collected from the hydrothermally altered Demirören area and analyzed for uranium, thorium (^{238}U and ^{232}Th) and potassium (^{40}K). The distributions of the activities of ^{238}U , ^{232}Th and ^{40}K in soil samples from the study site were evaluated using some statistics parameters and global average values of those elements. The activities range from 0,70 to 4,20 ppm for ^{238}U with an average of 2,43 ppm, 2,80 to 13,20 ppm for ^{232}Th with an average of 9,02 ppm, and 0,82% to 4,11% for ^{40}K with an average of 2,41% respectively. The obtained results for those elements are generally for lots of sample locations greater than the global average values of them. The concentrations were converted into respective concentration to Becquerel per kilogram (Bq kg^{-1}) using associated equations. It was affirmed from the statistical analysis that the radiological hazards occur as a result of contributions from the three naturally occurring radionuclides (that is, thorium, uranium and potassium). The values obtained in this study revealed that the sampled locations are contaminated zones for villager situated close to hydrothermally altered areas.

Keywords: Radiation exposure, exposure risks, hydrothermally alteration areas, Demirören (Gumushane, NE Turkey).

1. Introduction

In the geochemical sense, alteration is the state of equilibrium with the new environment to which the geological environment is exposed. Although there is some controversy about its definition, it is the adaptation of the minerals that make up the rocks to new minerals by the effect of magmatic fluids. In this case, meteoric waters as well as magmatic fluids have an impact on the process. This process may occur in the underground or shallow areas. Primitive rock chemistry changes as a result of this process which can be called hydrothermal alteration. While some elements are enriched in the environment, some elements can move away from the environment. While element enrichment may reach an economic value in some cases, enrichment by some elements may appear as environmental risk. Soils, especially formed in the alteration area, are radioactive as a result of primordial and/or cosmogenic radionuclides being present naturally. Radionuclides reach to soil through soil-borne photosynthesis and water

absorption, as well as natural radioactive elements of potassium (^{40}K), uranium, thorium and their daughters. Staying more than the required time in a natural radioactive contaminated area could be dangerous to human.

Thorium is a naturally occurring radioactive element and is almost present everywhere, at least in small amount. It can be seen in rocks, soil, surface water, groundwater, animals and plants. Most of the naturally seeing thorium exists as ^{232}Th (isotope). Thorium does not easily dissolve in water or evaporate from soil or water into the air. People living on contaminated soils in thorium can be exposed to thorium by inhaling contaminated dust or people eating food grown on this soil can be contaminated with thorium. Effects of being exposed to thorium through inhalation include cancers of different forms or it can result into damage of the body systems or result into death [1].

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Potassium is essential in the human-being but exposure to potassium causes some drawbacks in living beings, especially in humans. For example, high potassium concentration in the body is referred to as hyperkalemia. Besides, there are many negative effects of high potassium on human, such as stomach upset, nausea, diarrhea, weakness or tiredness, vomiting, tingling, intestinal gas, chest pain, listlessness, paralysis, mental confusion, dizziness, irregular heart rhythm or palpitation, low blood pressure etc. [2, 3].

Uranium can be found in low amounts especially in granitic rocks, however in soil and water. Prolonged exposure to high concentrations of uranium by inhalation etc. can cause many health problems such as chronic lung diseases, acute leucopenia, necrotizing periodontal disease, anemia, tumors in the bones, nasal and cranial nerves [4].

Alteration sites are not only important for mineral exploration studies but also for environmental risks. Because, if the elements with economic value are to be enriched at a desired level, the environment can be regarded as an ore deposits or mineralization area. Otherwise there is an increase over the average values of undesirable elements due to side effects, it

can be assumed that the environment is contaminated by those elements. These effects are seen as heavy metal contamination/pollution in soil and the studies on this subject are increasing day by day [5–9]. Generally, soils, especially derived from alteration area, can be radioactive as a result of primordial and/or cosmogenic radionuclides being present naturally. Radionuclides reach to soil through natural radioactive elements such as potassium (K), calcium (Ca), vanadium (V), germanium (Ge), selenium (Se), rubidium (Rb), thorium (Th) uranium (U), and their daughters. People living in such an environment for a long time, in other words, people living in such environments, face the risk of exposure to extreme radiation. As mentioned above, there are many effects of over-exposure to radioactive elements. So, radionuclide's activity concentrations and the risks associated with villager's exposure to these radioactive elements should be monitored. Considering all these, this study was carried out and the aim of this study was to investigate the radiation risk in Demirören hydrothermal alteration area (Gümüşhane-Turkey). Another aim of this study is to raise awareness about the risks faced by people living in such areas.

2. Regional geology and geological setting of the study area

The Eastern Pontides are divided into northern and southern parts by [10]. The study area is located to the south of the Eastern Pontides. The basement rocks of the Eastern Pontides are composed of Early Carboniferous metamorphic rocks [11] and Late Carboniferous Plutonic rocks [12–14]. The Early and Middle Jurassic volcano-sedimentary rocks lie unconformably on the basement rocks [15–17] and are cut by Mid- to Late Jurassic plutons [18, 19]. These units are overlain by the Late Jurassic to Early Cretaceous carbonates. The Late Cretaceous units that unconformably overlie these carbonate rocks consist of plutonic, volcanic and sedimentary rocks [20–23]. The Eocene volcanic and volcanoclastic rocks overlie the Late Cretaceous series [14, 24–27], and are intruded by plutons of similar age [28–36]. Post-Eocene uplift and erosion brought clastic input into locally developed basins [37]. In the Late Eocene, the region has remained largely above sea level with continuous minor volcanism and terrigenous sedimentation [38]. The Miocene and post-Miocene

magmatism are characterized by calc-alkaline to mildly alkaline compositions [39, 40], while the Miocene to Pliocene volcanism in the Ilıca-Kandilli area is represented by calc-alkaline in compositions [41, 42]. The youngest rocks in the region are Quaternary travertine and alluvial rocks.

Demirören alteration area is situated in the southern zone of the Black Sea Tectonic Unit (Eastern Pontides). The oldest rocks of the area are upper Cretaceous volcanic rocks. These rocks consist of andesite basalt and their pyroclastic. These rocks pass upward to same aged limestone. The limestone unit outcrops southwest of Demirören village, outside the study area [43]. These rocks are unconformably overlain by Eocene limestones with basal conglomerate. The limestone unit is overlain by Eocene volcano-clastic consisting of andesites, basalts and their pyroclastic. The Eocene volcano-clastic rocks are cut by the Eocene acidic intrusions both within and around the study area (Figure1).

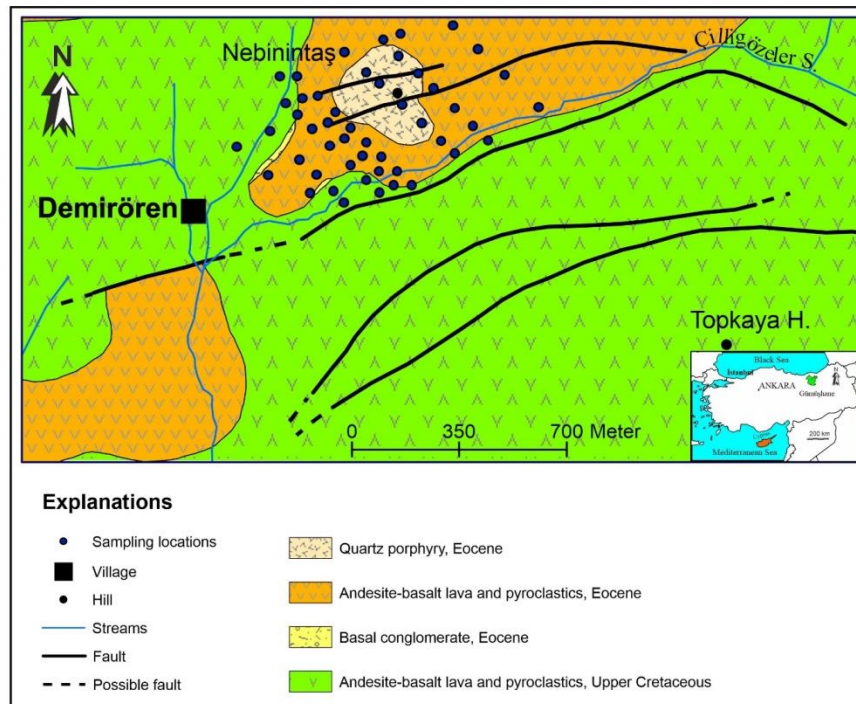


Figure 1. The map of sampling location and geology (after [7-8, 43]).

Intensive hydrothermal alteration has been developed in Eocene volcanic and plutonic rocks in the study area. The types of hydrothermal alteration observed in the field are silicification, hematization, limonitization, argillic alteration. These alteration

types developed in and around the plutonic rocks are surrounded by a lower temperature product, a propylitic alteration zone. Hydrothermal alteration processes are partly accompanied by metasomatic processes as well as weathering.

3. Sampling, analysis and calculation of the parameters

Forty-nine soil samples were collected at 20-30 cm depth from B zone in a rectilinear grid at equal intervals from approximately every 100 m in NW–SE and NE–SW directions along evenly spaced lines (Figure 2). Since the samples provided the best enrichment in B zone.

All collected samples were dried at ambient temperature and then heated at 60 °C for 2 hours. In order to obtain suitable grain size, samples were ground with a mill and passed through an 80-mesh sieve and analyzed for some radioactive elements, such as uranium, thorium (^{238}U and ^{232}Th) and potassium (^{40}K) by Inductively Coupled Plasma-Atomic Emission Spectrometry (ICP-AES) and Inductively Coupled Plasma-Mass Spectrometry (ICP-MS) at ACME Laboratory (Canada). The

concentrations of potassium, uranium and thorium in each soil sample were given in percent (%) and parts per million (ppm) respectively.

The concentrations were converted into respective concentration to Becquerel per kilogram (Bq kg^{-1}) using associated equations and results were assessed statistically. The equations of conversion concentration to Becquerel per kilogram (Bq kg^{-1}) are in accordance with International Atomic Energy Agency [44] and [45] models and as follows:

$$\begin{aligned} 1\% \text{ of } ^{40}\text{K} &= 313 \text{ Bq kg}^{-1} \\ 1 \text{ ppm of } ^{238}\text{U} &= 12.35 \text{ Bq kg}^{-1} \\ 1 \text{ ppm of } ^{232}\text{Th} &= 4.06 \text{ Bq kg}^{-1} \end{aligned}$$



Figure 2. A view of the study area.

4. Results and discussion

The distributions of the activities of the radioactive elements, ^{238}U , ^{232}Th and ^{40}K in soil samples from the study area were evaluated using some statistics parameters and global average values of those

elements. The activity concentrations' descriptive statistics and the converted results (in Bq kg^{-1})'s descriptive statistics are revealed in Table 1 and Figure 3.

Table 1. Concentrations of natural radioactivity in soil samples of Demirören

	K		Th		U	
	%K	Bq_kg-1	Th (ppm)	Bq kg-1	U (ppm)	Bq kg-1
Mean	2.41	753.12	9.02	36.64	2.43	30.02
St.Error.	0.08	26.46	0.35	1.42	0.09	1.12
Median	2.43	761.63	9.40	38.16	2.50	30.88
St.Dev.	0.59	185.24	2.45	9.95	0.64	7.85
Variance	0.35	34312.61	6.01	99.04	0.40	61.66
Minimum	0.82	255.62	2.80	11.37	0.70	8.65
Maximum	4.11	1285.91	13.20	53.59	4.20	51.87
Number	49	49	49	49	49	49

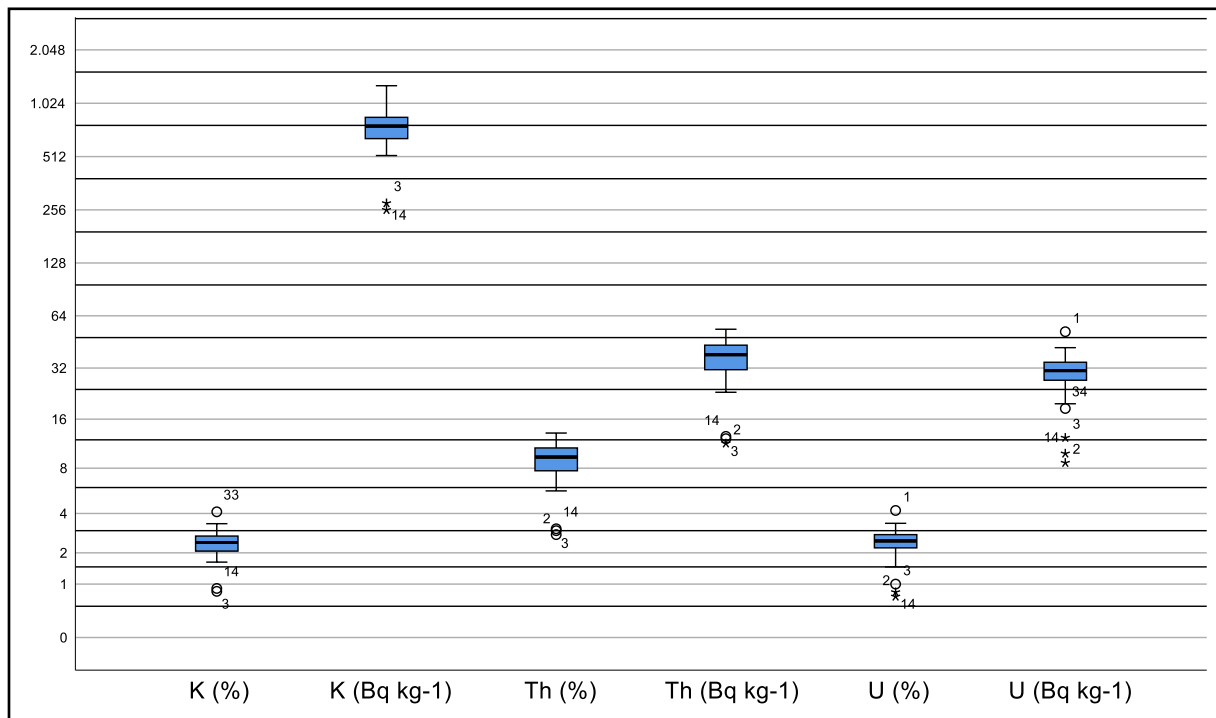


Figure 3. Box plot diagrams of concentrations of natural radioactivity in soil samples of Demirören.

The activities range from 255,62 to 1285,91 Bq kg⁻¹ for ²³⁸K with an average of 753,12 Bq kg⁻¹; 11,37 to 53,59 Bq kg⁻¹ for ²³²Th with an average of 36,64 Bq kg⁻¹; 8,65 to 51,87 Bq kg⁻¹ for ²³⁸U with an average of 30,02 Bq kg⁻¹ respectively. All of the results obtained or ⁴⁰K have higher values than the recommended limit of 400 Bq kg⁻¹ as reported by [14]. More than 75% of the obtained results for ²³²Th are greater than the global average value of 30 Bq kg⁻¹; nearly 25% of the obtained results for ²³⁸U are greater than the global average value of 35 Bq kg⁻¹ [46, 47]. Based on these data it was understood that; the obtained results of ²³⁸U, ²³²Th and ⁴⁰K elements are generally for lots of sample locations greater than the global average values of them.

On a large scale, the obtained all results for those elements are generally for lots of sample locations greater than the global average values of them. So, it

was affirmed from the data and statistical evaluations that the radiological hazards occur as a result of contributions from the three naturally occurring radionuclides (that is, thorium, uranium and potassium). The values obtained in this study revealed that the most sampled locations are contaminated zones for inhabitants close to hydrothermally altered areas (Figure 4-6). Demirören village is one of the crowded villages of the region and the villagers are living with their land. People who have such a close relationship with the soil are exposed to radioactive elements as being over-exposed by inhalation or by the food they eat. Taking into consideration these situations, it is suggested to investigate the effect of radiation on people who live in the area by carrying out detailed studies. According to the results of the detailed studies to be obtained, even if possible, these villagers should be moved to another settlement.

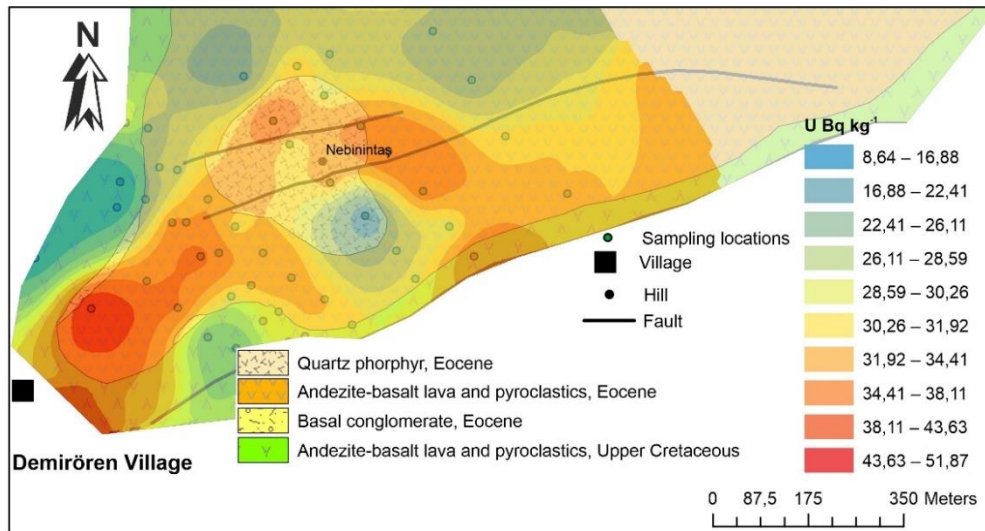


Figure 4. Distribution map of activity concentrations of U in Bq kg⁻¹ (The map was drawn using the ordinary kriging with spherical method, with smothing factor 0.2).

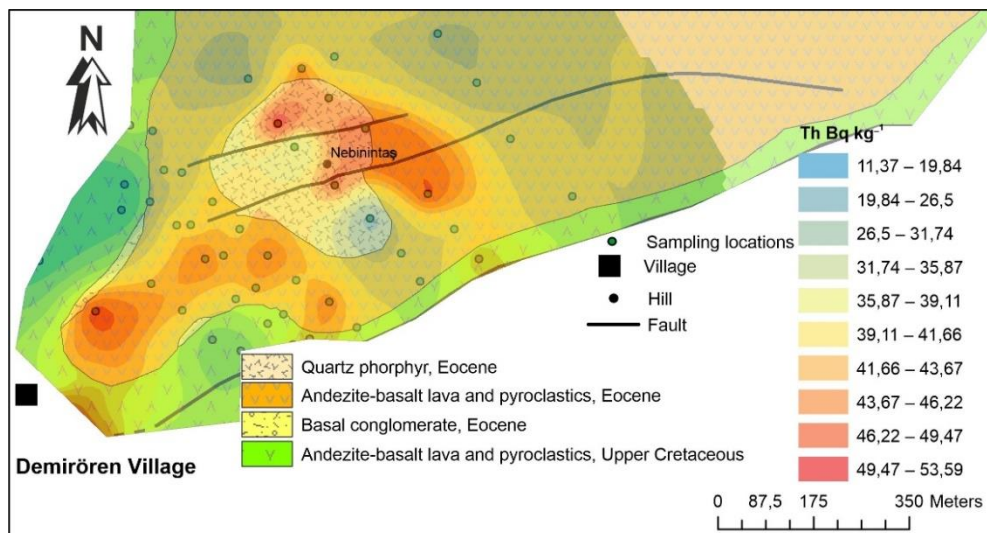


Figure 5. Distribution map of activity concentrations of Th in Bq kg⁻¹ (The map was drawn using the ordinary kriging with spherical method, with smothing factor 0.2).

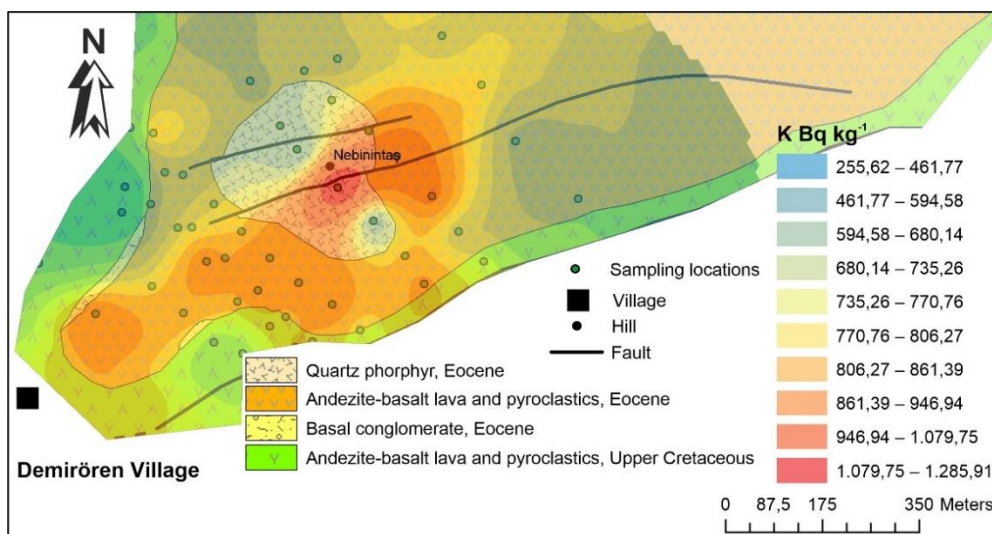


Figure 6. Distribution map of activity concentrations of K in Bq kg⁻¹ (The map was drawn using the ordinary kriging with spherical method, with smothing factor 0.2).

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