

Assessing Heavy Metal Pollution and Usage Characteristics of Surface Water Resources of Tavşanlı District (Kütahya, Turkey)

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Abstract – The study examines the chemical properties of surface waters in the Tavşanlı district to determine heavy metal pollution, particularly regarding their suitability as drinking water. Thirteen water samples were taken in October (2018) to analyze surface waters' chemical properties in the study area. Chemical analyses of these samples were conducted, measuring As, Pb, Fe, Mn, Cr, and Ni concentrations to reveal heavy metal pollution. The study findings reveal that the levels of Pb, Fe, Mn, Cr and Ni in the water samples meet the regulatory threshold. However, the concentrations of As in the water specimens scrutinized vary from 8.2 µg/L to 739.1 µg/L. The As content of the water sample taken from Sekiören pond alone was measured to be below the threshold, at 8.2 µg/L. In all other water samples, arsenic was found to be significantly above the safe drinking water limits, rendering these waters unsuitable for human consumption. The contamination can be largely attributed to mining sites in the surrounding area as their wastewater mixes with the surface water. Managing mining activities in the region is essential to protect water sources from heavy metal pollution.

Keywords – Surface Water, Heavy Metal, Pollution, Tavşanlı

I. INTRODUCTION

Water is a vital resource for sustaining human life. Nonetheless, water pollution presents a major impediment to the sustainable development of nations. Reasons such as unplanned and rapid urbanization developing in parallel with the increase in human population, increase in industrial establishments, acceleration of mining activities have negatively affected the existing water resources. Today, the most easily utilized water resources are surface waters. However, surface waters lose their usability due to unfavorable conditions created by environmental factors and become unusable especially in terms of quality.

In developing countries, 95% of domestic wastewater, 70% of commercial wastewater and a significant amount of mining wastes are discharged untreated into receiving environments. As a result, clean water resources are being polluted and access

to safe drinking water is becoming a major problem [1], [2]. Heavy metals are chemical elements that can be found naturally in the environment but are released into the environment by human activities. Heavy metal pollution in water resources occurs as by-products of human activities such as industrial wastes, agricultural activities, mining and sewage. These heavy metals can contaminate water resources by mixing with water. Common heavy metals comprise of mercury, lead, arsenic, cadmium and nickel. Arsenic, in particular, is a significant pollutant that leads to the deterioration of water quality and renders it unusable [3].

Agriculture and animal husbandry are the main sources of livelihood in Tavşanlı district, which is one of the important districts of Kütahya province. In addition, mining activities are quite common in the region. The richest lignite deposits of our country are located in this region. In addition, private coal and magnesite quarries are operated and

contribute to the region economically [3], [4]. In this study, the effects of these environmental pollutants on surface waters in the region were evaluated especially in terms of heavy metal pollution. In addition, the usage characteristics of the waters in terms of drinking water were analyzed.

II. MATERIALS AND METHOD

A. The study area

In the Tavşanlı plain, which was selected as the study area, Tavşanlı district and many village settlements are located. Tavşanlı district is located in Kütahya province in the Central Aegean region of Turkey (Fig. 1).

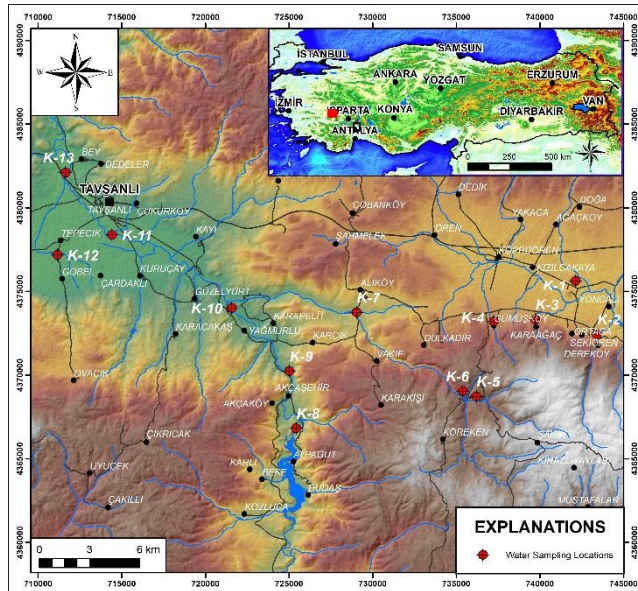


Fig. 1 Location map of the study area

The most important surface water flowing in the Tavşanlı plain is Orhaneli Stream. The stream originates from Kızıldağ and flows in the north direction, adding many tributaries to its bed, which flow both continuously and seasonally. Orhaneli Stream, which flows in the northwest direction while passing through the Tavşanlı plain, then mixes with Emet Stream and flows into Uluabat Lake. Orhaneli stream, which has a flow path of approximately 200 km, is used as drinking water by the local people. The main source of drinking water in the region is Kayaboğazı dam lake. As can be seen in Fig. 1, this reservoir is fed by İğneli stream, Yılanlı stream and Orhaneli stream and thus it is affected by the chemical properties of many surface waters. Güdül Stream, which flows in the east of the plain, is a stream that flows with the feeding of the

springs with low flow rate in the region and eventually mixes with Orhaneli Stream [5].

B. Method

In order to determine the heavy metal pollution, water quality and utilisation characteristics of surface waters in the region, 13 water samples were taken in October (2018). Water samples were taken from Kocasu stream, Sekiören Pond, Karaağaç Pond, Gümüşköy Pond, Güdül Stream, Kayaboğazı Dam Lake, Orhaneli stream and Tepecik canal and sample locations are given in Fig. 1.

Water samples were collected from each sample site for anion and cation analyses. One of the samples was acidified with a few drops of 0.5% nitric acid (HNO_3) for cation analysis. The parameters of pH, temperature (T ; $^{\circ}\text{C}$), electrical conductivity (EC ; $\mu\text{S}/\text{cm}$), and total dissolved solids (TDS ; mg/L) were determined in situ using the YSI Professional Plus multi-parameter instrument. Chemical analysis of the samples was undertaken at the Bureau Veritas Mineral (Canada) Laboratory and the Geothermal Energy, Groundwater, and Mineral Resources Research and Application Laboratory at the Geological Engineering Department of the SDU (Isparta).

III. RESULTS

Water samples were taken from Kocasu stream, Sekiören Pond, Karaağaç Pond, Gümüşköy Pond, Güdül stream, Kayaboğazı Lake, Orhaneli Stream and Tepecik-channel water in order to reveal the usage characteristics of surface waters in the study area as drinking water and heavy metal pollution. The pH, temperature and EC values of the samples were measured in situ and the results are given in Table 1. Major ion and heavy metal concentrations of the water samples are presented in Table 2.

When the general chemical properties of the waters are analyzed, it is seen that the pH values of the water samples are greater than 7 (between 7.6 - 8.3) and indicate the "basic character" water class. Specific electrical conductivity values of the water samples vary between 309-817 $\mu\text{S}/\text{cm}$.

Table 1. In-situ measurement results of water samples [3]

Station	Number	pH	°C	EC
Yoncalı / Kocasu stream	K1	8	21,20	817
Sekiören Pond	K2	8,2	10,80	371
Karaağaç Pond	K3	8,2	10,70	309
Gümüšköy Pond	K4	8,2	10,70	441
Güdül stream 1	K5	8,3	11,20	503
Güdül stream 2	K6	8,1	10,80	533
Güdül stream 3	K7	8,3	11,20	434
Kayaboğazı Lake	K8	8,1	12,00	429
Orhaneli stream 1	K9	8,3	12,70	431
Orhaneli stream 2	K10	8,3	12,60	456
Orhaneli stream 3	K11	8,1	13,10	461
Tepecik / channel water	K12	7,7	13,10	654
Orhaneli stream 4	K13	7,6	12,90	535

Table 2. Analysis results of water samples

Parameters (mg/L)	Min.	Max.	Mean	Std. Deviation
Na	2,22	16,6	6,5	3,95
K	1	5,21	2,67	1,28
Ca	47,54	104,74	63,58	15,41
Mg	11,54	49,69	29,33	10,92
HCO ₃	0	26	11,53	7,88
CO ₃	161	328	224,30	47,50
Cl	8,52	21,3	12,18	3,43
SO ₄	11,64	28,52	15,90	4,19
NO ₃	0,01	13,36	2,9	3,57
Mn	0,00037	0,11881	0,0236	0,0363
Pb	0,0001	0,0009	0,000292	0,00026
As	0,0082	0,7391	0,1555	0,2394
Fe	0,01	0,01	0,01	0,000
Cr	0,0005	0,0182	0,0022	0,00483
Ni	0,0002	0,0037	0,0008	0,001

The highest EC value was measured in Yoncalı / Kocasu stream, and it is the richest sample especially in terms of CO₃ ion. Na values of the water samples varied between 2.22 and 16.60 mg/l, Ca values varied between 47.54 and 104.74 mg/l and the highest Na and Ca values were determined in the sample taken from Yoncalı / Kocasu stream. Cl values of the surface waters examined within the scope of the study vary between 8.52 and 21.30 mg/l and SO₄ values vary between 11.64 and 28.52 mg/l. While Cl and SO₄ values are low in the water sample taken from Sekiören Pond, the samples taken from Yoncalı / Kocasu stream and Tepecik Canal water have high Cl and SO₄ content.

In terms of heavy metals, Mn, Pb, As, Fe, Cr and Ni contents of the samples were determined.

According to the obtained results, arsenic amounts in the samples were measured at very high values. In the study conducted by [4], surface waters in the region contain higher amounts of arsenic than groundwater. This situation indicates that the arsenic source observed in the waters is anthropogenic in relation to the mining activities carried out in the region.

IV. DISCUSSION

Many physical and chemical parameters that should be sought in waters to be used as drinking water, in other words, which should meet the standard, have been determined. While determining these limit values, especially the minerals and ions needed for human health and their daily intake doses are taken into consideration. In addition, it should not contain any specific pollutants and heavy metals above certain concentrations that will be harmful to health. Otherwise, consumption of contaminated water by people will bring serious health problems [6].

In this context, many national and international standards have been prepared for drinking water criteria and limit values of each criterion. The drinking water standard published by the "Turkish Standards Institute TSE-266, [7]" in April 2005 is the valid assessment guide in our country. As international drinking water standards, there are standards of the World Health Organisation [8]. The analysis results of the water samples examined within the scope of the study were compared with the limit values specified by [7], [8]. According to the evaluation, sample K2 taken from Sekiören Pond among the surface water samples is suitable for use as drinking water. However, arsenic concentrations of all other water samples are above 10 µg/l and are not suitable for use as drinking water. Especially water samples K5, K6 and K7 contain very high amounts of As.

Emet boron mining, the Tunçbilek Thermal Power Plant and the Gözeçukuru As-Sb-Pb-Zn mine are situated in the vicinity of the study area. Emet boron mining and the Gözeçukuru As-Sb-Pb-Zn mine are both found upstream of the study area, whereas the Tunçbilek Thermal Power Plant is located downstream, as per the direction of water flow. [9] reported that the wastes of Gözeçukuru As-Sb-Pb-Zn mine are rich naturally in arsenic, lead

and antimony and this mining activities are cause the anthropogenic contamination for surface waters due to leakage of As, Pb, Sb and Zn from the mine waste pools. Borate mining has been conducted for roughly 60 years in the Emet basin situated in the southwest of the study region. The area's soils and waters contain excessive amounts of As and Sb-bearing minerals due to magmatic/volcanic units and hydrothermal activities. Additionally, the region is abundant in epithermal mineralization [10].

V. CONCLUSION

The study investigated the pollution status of surface waters (lakes, ponds, and streams) used for potable purposes in Tavşanlı (Kütahya) district pertaining to heavy metals and assessed their suitability as drinking water sources. Thirteen water samples were analyzed in October 2018, revealing the water's chemical properties and quality. After comparing the water sample analysis results with the limit values specified by TSE-266 and WHO (2008), it was discovered that only sample number K2 collected from Sekiören Pond adhered to all parameters and was deemed appropriate for drinking purposes. However, arsenic concentrations in all other water samples exceeded the limit of 10 µg/l, therefore rendering them unsuitable for human consumption.

The uncontrolled release of wastewater from mining activities is the primary threat to surface water quality in the region. The Gözeçukuru mine (As-Sb-Pb-Zn mine) is situated in the eastern part of Tavşanlı plain, and the Güdül Stream runs adjacent to the mine's tailings ponds. Contaminants such as arsenic, lead, and antimony are commonly found in these waste ponds, making them the major source of pollution in the area, particularly for surface waters.

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REFERENCES

- [1] W.J. Cosgrove, F.R. Rijsberman, "Challenge for the 21st century: Making water everybody's business", *Sustainable Development International*, vol. 2, pp. 149-156. 2000.
- [2] J.D. Gomez, A.C. Nakat, "Community participation in water and sanitation", *Water International*, vol. 27(3), pp. 343-353. 2002.
- [3] Ş. Şener, E. Şener, "Hydrogeochemistry of Tavşanlı (Kütahya) Plain Surface Waters and Evaluation of Water Quality by Water Quality Index (WQI) Method" *Mühendislik Bilimleri ve Tasarım Dergisi*, vol. 10(2), pp. 380-391, 2022.
- [4] Ş. Şener, M. Karakuş, "Investigating water quality and arsenic contamination in drinking water resources in the Tavşanlı District (Kütahya, Western Turkey)" *Environmental Earth Sciences*, vol. 76, pp. 1-17, 2017.
- [5] State Hydraulic Works "Tavşanlı Ovası Hidrojeolojik Etüd Raporu, Devlet Su İşleri Genel Müdürlüğü. Jeotek. Hiz. ve Yeral. Su. Dai. Bşk., 107 p., 1978.
- [6] Ş. Şener "Hydrogeochemical Investigation of Eğirdir Lake Water and Bottom Sediments", Süleyman Demirel University, Institute of Science and Technology, Geological Engineering Department, Nov, 2010.
- [7] TSI 266 "Standards for drinking waters. Turkish Standards Institution", Ankara, Turkey, 25 p. 2005.
- [8] WHO, World Health Organisation Guidelines for Drinking-water Quality, Third Edition Incorporating The First and Second Addenda, WHO Publication, Geneva, 668 p. 2008.
- [9] Ş. Arslan, M. Çelik "Assessment of the Pollutants in Soils and Surface Waters Around Gümüşköy Silver Mine (Kütahya, Turkey). *Bull Environ Contam Toxicol*, vol. 95(4), pp. 499-506, 2015.
- [10] C. Özkul, E. Çiftçi, N. Köprübaşı, S. Tokel, M. Savaş "Geogenic arsenic anomalies in soils and stream waters of Neogene Emet basin (Kütahya-Western Turkey)". *Environ Earth Sci*, vol. 73(10), pp. 6117-6130, 2015.