The International Journal of Engineering and Science (IJES)
|| Volume || 14 || Issue 7 || July || Pages || PP 01-09 || 2025 ||
ISSN (e): 2319 – 1813 ISSN (p): 2319 – 1805

Investigation of Water Quality of Doğantepe (Altındağ/Ankara) Forest and Stream in Terms of Heavy Metals

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ABSTRACT
In our country, the risk of urban flooding continues to rise due to climate change, irregular construction, rapid urbanization, population growth, inadequate drainage systems, and insufficient infrastructure. In Ankara, the capital city of Türkiye, in addition to urban flood risks, there is also a threat of flooding from the streams and creeks that pass through the city. Doğantepe, where these risks are frequently experienced, located in the Altındağ district of Ankara and one of the oldest settlements in Ankara. Doğantepe is located at a latitude of 40°01′ N and a longitude of 32°98′ E. In the present study, the concentration levels of ions reflecting the natural quality of forest and stream water in the Doğantepe were investigated by the Inductively Coupled Plasma Optical Emission Spectroscopy (ICP-OES) method. 19 heavy metals and salinity were examined via chemical analyses conducted on 3 water samples from the study areas. Chemical analysis of water samples collected from 3 distinct locations revealed average concentrations of cations primarily responsible for salinization, including sodium, potassium, calcium, and magnesium, along with nineteen heavy metals. The water quality of Doğantepe stream and forest water were found to be second class according to the criteria of Water Pollution Control Regulation in Türkiye. In addition, Doğantepe-2 forest water was found to be contaminated by domestic and industrial waste. No previous research has been done on the quality of stream and forest water in the Doğantepe, so our study can guide protection of the future surface water quality of the Doğantepe that undergoing urban transformation.

KEYWORDS; *Doğantepe stream water, Doğantepe forest water, heavy metal index, salt stress, water quality*

Date of Submission: 10-07-2025 Date of acceptance: 23-07-2025

I. INTRODUCTION

Surface-water resources such as streams, rivers, and forest basins are important for use in agricultural activities as well as for providing clean and safe drinking water [1]. Forested watersheds provide approximately 75% of the world's accessible freshwater resources on which over half of the world's people depend on for domestic, agricultural, industrial and environmental purposes. Additionally, forests supply clean water to more than 85% of the world's major cities, including New York and Mumbai [2]. Nevertheless, in recent years, forests are converted to non-forest uses such as mining, and other economic activities in our country, as well as all over the world, which raises concerns of disruption of aquatic webs and also causes contamination of basins with heavy metals (HMs) and similar pollutants.

HMs refers to a group of metalloids and metals with densities greater than 5g/cm³ that exhibit toxicity on living organisms and have been branded as one of the foremost sources of chemical water pollution [3]. HMs are classified into categories of either essential or non-essential metal ions based on their role in various biochemical processes. Essential heavy metals, such as copper (Cu), selenium (Se), zinc (Zn), and iron (Fe), are required in small amounts for metabolic and physiological functions [4,5]. While necessary for maintaining health, they can become toxic at higher concentrations (1-10 ppm) [6-8]. On the other hand, non-essential heavy metals, such as cadmium (Cd), mercury (Hg), lead (Pb), and arsenic (As), are known to be extremely toxic even at low concentrations and cause health problems including autoimmune diseases, organic diseases, and neurological defects [9-10].

The concentrations of the HMs for inland waters and the variation in these concentrations according to water quality classification are presented in Table 1 (Republic of Türkiye Ministry of Agriculture and Forestry/Regulations for Water Pollution Control [11].

Heavy metals (μg/L)	Water Quality Class				Heavy metals (μg/L)	Water Quality Class			
	I	II	III	IV		I	II	III	IV
Ag	-*	-	-	-	Fe	300	100	500	>500
As	≤20	50	100	>100	Mn	100	500	300	>3000
B	1000	1000	1000	>1000	Ni	20	50	20	>200
Be	-	-	-	-	Pb	10	20	50	>50
Cd	3	5	10	>10	Sb	-	-	-	-
Co	≤10	20	200	>200	Tl	-	-	-	-
Cr	≤20	50	200	>200	V	-	-	-	-
Cu	≤20	50	200	>200	Zn	200	500	2000	>2000

* No guideline

Table 1. **Allowable upper limit values of various heavy metals according to water quality classes**

According to the WPCR, inland surface waters (rivers, streams, lakes, springs, etc.) are classified into four general classes: 1st class water refers to high quality water, 2nd class water refers to slightly polluted water, 3rd class water refers to polluted water and 4th class water refers to very polluted water.

HMs can become strongly toxic to both the environment and humans when they exceed the permissible limits. The World Health Organization (WHO) estimates that more than 60-70% of total acute and chronic disease is linked to environmental factors including exposure to heavy metals. Therefore, understanding characteristics of the water bodies comes from natural sources and used for freshwater aquaculture production, and preventing contamination, will definitely help to maintain ecological balance. It is therefore necessary to periodically check the physical, chemical and biological parameters in water bodies [12].

There have been many studies on water bodies and their quality index. Yasin et al., assessed spring water in Shawre Valley, Iraq, using Hydrogen Ion Concentration (pH), electrical conductivity (EC), total dissolved solids (TDS), and Calcium (Ca^{2+}), Magnesium (Mg^{2+}), Sodium (Na^{+}), Potassium (K^{+}), Chloride (Cl^{-}), Sulphate (SO_4^{2-}), Nitrate (NO_3^{-}), and showed that water quality is unfit for drinking consumption [13]. Dinka studied water quality on the Awash River in Ethiopia, using physicochemical parameters like pH, EC, TDS, and Na^{+}, K^{+}, Ca^{2+}, Mg^{2+} etc. and evaluated the statistical correlation between these parameters [14]. Akram et al. used the total hardness (TH), alkalinity, and salinity indices to evaluate the ground water quality for the nine major cities in Sindh, Pakistan and showed that water samples from three cities is poor for drinking and commercial usage [15]. Musa et al. assessed the suitability of surface water for irrigation purposes in the Maikunkele Fadama region of Niger State, using Na^{+}, K^{+}, Ca^{2+}, Mg^{2+}, besides and five heavy metals (manganese (Mn), copper (Cu), zinc (Zn), and iron (Fe)) and showed that the water quality is fit to be used as irrigation water [16]. Al-humairi and Rahal used the sodium adsorption ratio (SAR), Na%, Mg%, and exchangeable sodium percentage (ESP) indices to evaluate the drainage water quality for the Al-Dujaila River in Iraq and showed that diluted drainage water was not suitable for either irrigation or human use [17]. Both Mg^{2+} and Ca^{2+} ions (major ions) are natural components of surface water and groundwater sources, and their presence can be influenced by geochemical structure, type and intensity of water supply, land use in the catchment area, weather conditions, type of soil etc. [18]. The amount of major ions in water defined as salinity and dramatic increases in salt concentrations in creeks, streams, rivers, or lakes are referred to as freshwater salinization syndrome (FSS), which can have undesirable effects on health, the environment, and the broader economy. For example, high salinity levels may cause corrosion of water distribution pipes and increase the mobility of elements from pipes to groundwater and surface water. Salinization can also increase nitrogen transition from water to soil, therewith increasing nutrient concentration, which can lead to hypoxic water conditions, and algal blooms. Beyond the loss of biodiversity, saline water is unsuitable for drinking, domestic, agricultural, and industrial water uses. Moreover, the consumption of water with excessive salt is a major risk factor for the kidney disease. Chechet et al. used the ICP–OES method to determine the content of 15 mineral elements in drinking water, which came to the laboratory from the settlements of Ukraine [19]. Ostrega et al. determined some elements in water samples collected near Pb-Zn mining using ICP-MS and ICP-OES methods [20]. SPE-ICP-OES method was used determination of trace element for the Karaj River water in Iran [21]. Baralkiewicz et al. compared ICP-OES and ICP-MS data in the determination of trace elements (aluminum (Al), strontium (Sr), lithium (Li), Cu, Pb, chromium (Cr), vanadium (V), and nickel (Ni)) in lake water [22].

The aim of this study, analyze ions causing the salinity that K^{+}, Mg^{2+}, Na^{+}, and Ca^{2+} and heavy metals aluminum (Al), arsenic (Ar), antimony (Sb), beryllium (Be), boron (B), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), (lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), selenium(Se), silver (Ag), thallium (Tl), vanadium (V), and zinc (Zn)) in the Doğantepe forest and stream waters by the ICP-OES method.

This study provided valuable insights into the dynamics of salinization by proper monitoring and reporting of the chemical properties of Doğantepe stream and forest waters. Additionally, the water quality in Doğantepe with respect to its heavy metal concentration was evaluated by heavy metal pollution index (HPI).

II. MATERIAL AND METHODS

Study area

This study was conducted at three selected locations as the research area in the stream and forest waters of the Doğantepe. Doğantepe neighborhood is located in the Altındağ district of Ankara with the gps coordinates of 40°01' N latitude and 32°98' E (Figure 1). Altındağ is one of the metropolitan districts of Ankara Province, Türkiye. Its population is 413.994, according to Turkish Statistical Institute (TÜİK) data [23]. It is also located close to the furniture-manufacturing district, called “Siteler” industry site.

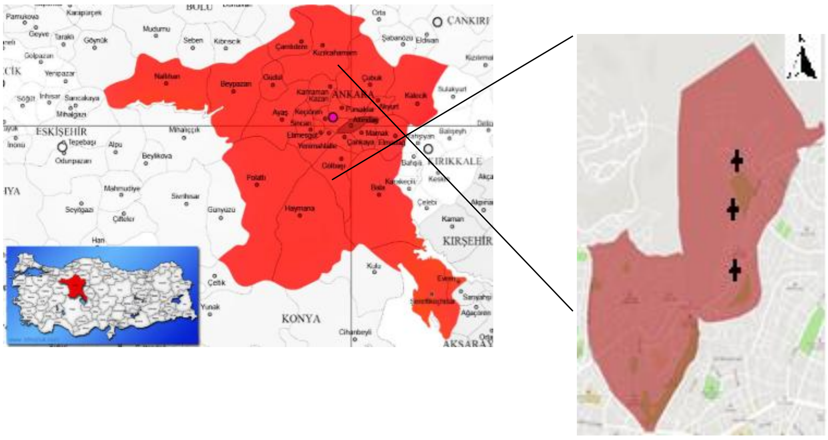

Figure 1. Research area and measuring stations

Data collection

In our study, surface water samples at the sampling sites were taken during the summer months. Surface water samples for the analysis of water quality parameters were collected from the near-surface layer at depths no greater than 0.5 m. Water samples were collected in 1 L polyethylene bottles and transported to the Ministry of Health-Ankara Public Health Laboratory in accordance with the 'Standard Methods for the Examination of Water and Wastewater/1060 Collection and Preservation of Samples' [24]. The purpose of determining metal content, the collected samples were filtered by 0.45 µm membrane filters to remove sediments and debris. The pH of the samples was adjusted to pH < 2 by means of 1 mL of 1:1 diluted nitric acid (from %65 HNO_3, Merck). Water samples were stored at 4°C in ice containers until analysis.

Standard solutions and reagents

ICP multi-element stock solution XVI (MerckCertipur®) for each element, and %65 nitric acid (Merck, Suprapur®) were used during analyses. The ultra-pure water (18.2 MΩ cm^{-1}) was produced by a Milli-Q Ultrapure Water System (Millipore, Bedford, MA). All solutions, samples and reference materials, were prepared in 5% v/v HNO_3.

ICP-OES instrumental parameters and validation

Metal concentrations were quantified utilizing an Agilent 720 ICP-OES instrument (Agilent, Santa Clara, CA 95051 United States). The instrument was equipped with CCD detector and US FDA’s 21 CFR 11 version 4.1.0 software for data acquisition and processing. The water samples were introduced into the plasma by means of a One-Neb nebulizer, a sheath gas torch, and a cyclonic spray chamber with a rotation rate of 0.3 revolutions per second. Regarding the specification of the argon gas plasma, the forward powers was 1000 W. Moreover, the plasma, auxiliary, and nebulizer gas flow rates were set at 15.0, 1.50, and 0.6 L/min, respectively. Sample uptake time of 30.0 sec, delay time of 5 sec, rinse time of 30 sec, instrument stabilization time of 15 sec and time between replicate analysis of 3 sec was maintained *during* the studies for ICP-OES. The wavelengths of the elements measured in the devices were 167.19 nm, 328.068 nm, 188.980 nm, 249.772 nm, 313.042 nm, 214.439 nm, 238.892 nm, 267.716 nm, 327.395 nm, 238.204 nm, 184.887 nm, 257.610 nm, 231.604 nm, 220.353 nm, 206.834 nm, 196.026 nm, 190.794 nm, 292.401 nm, 213.857 nm which corresponds to the most sensitive emission wave length of Al, As, Ag, B, Be, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Sb, Se, Tl, V, Zn respectively. Each measurement was made 3 times on the ICP-OES device, and the mean value of these 3 repetitions was calculated.

Salinity

Among the salinity-causing ions, Na^{+} is considered the major ion contributing to water salinity, while Mg^{2+}, Ca^{2+}, and other ions in small concentrations contribute to salinity. Worden et al. used ICP-OES and ICP-MS for the determination oilfield formation water with total dissolved salt values of up to 230 mgL^{-1} [25]. Mitko and Bebek investigated K^{+}, Ca^{2+}, and Mg^{2+} concentrations in highly saline water samples by ICP-OES [26].

In our study, a routine procedure was described for the ICP-OES determination of Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} in concentration levels in river and forest water samples of Doğantepe neighborhood. The wavelengths of the elements measured in the devices were 589.592 nm, 766.491 nm, 396.847 nm, 279.553 nm which corresponds to the most sensitive emission wavelength of Na^{+}, K^{+}, Ca^{2+}, and Mg^{2+} respectively. An internal standard was used to correct for matrix interferences and instabilities.

Heavy metal pollution index (HPI)

The Heavy Metal Pollution Index (HPI) is one of the most effective techniques for evaluating water quality, as it reflects the combined effect of heavy metals in water sources [27,28]. The HPI index provides a clear representation on the suitability of water for drinking and domestic use and helps to identify and address any potential health hazards. The HPI is computed with the formula given below:

$$\mathrm{HPI} = \frac{\sum_{i=1}^{n} \mathrm{WiQi}}{\sum_{i=1}^{n} \mathrm{Wi}} \quad (1)$$

where W_i is the unit weightage of the parameter; Q_i is the sub-index element; and n is the number of parameters considered.

The unit weightage of each parameter (W_i) is computed by the following equation:

$$\mathrm{Wi} = \frac{k}{\mathrm{Si}} \quad (2)$$

Here, k is the factor of proportionality and k is taken equal to one for all metals in the literature [28,29], and Si is the recommended standard value according to WHO guidelines for the relevant elements [30].

The subindex Qi can be computed by using the following expression:

$$\mathrm{Qi} = \left(\frac{ci}{\mathrm{Si}}\right) x\ 100 \quad (3)$$

Where, c_i is the measured concentration in µg/L.

HPI has been divided into two categories to determine the quality of the water: If the HPI <100, it implies a low level of heavy metal pollution that is the water is safe for drinking; If the HPI>100, it indicates that the water is polluted with heavy metals and is not suitable for drinking purposes [31]. The obtained data were evaluated according to the Water Pollution Control Regulation (SKKY), the Turkish Drinking Water Standard (TS 266) [23], the World Health Organization (WHO, 2022) [32], and the HPI framework.

IV. RESULT VIEW

Water salinity

The effects of salinization on water samples have been estimated by testing Na^{+}, K^{+}, Mg^{2+}, and Ca^{2+} ions. The accumulated concentrations of salts and the results of the analysis from three sampling stations are presented in Table 2. The drinking water guidelines of the World Health Organization WHO (WHO, 2022), and Turkish Drinking Water Standard TS 266 (TS 2005) were taken into consideration for the purpose of comparison.

Metal (mg/L)	Doğantepe stream water	Doğantepe forest water-1	Doğantepe forest water-2	WHO (2022)	TS 266 (2005)
Sodium (Na)	0.408640	38.177458	32.358891	200	175
Potassium (K)	0.024071	0.827606	2.511206	-	12
Magnesium (Mg)	0.170443	37.096701	15.049352	-	50
Calcium (Ca)	1.109522	143.741759	79.806572	100	200

* No guideline

Table 2. Descriptive statistics of the chemical attributes of the water samples collected at three different sites

Ca^{2+}: The table above clearly shows that Ca^{2+} induced the highest toxicity compared to the other cations. The maximum concentration of Ca^{2+} is ~143.74 mg/L, reported in Doğantepe forest water-1, and the minimum concentration is reported in the Doğantepe stream water whose value is 1.10 mg/L. While the value of

calcium was within the permissible limit for WHO (2022) but exceed the maximum permissible limit of Ca^{2+} of recommended standards of TS 266 (2005).

Na^+: Sodium occurs naturally in seawater, lakes, and inland water. The maximum amount of sodium is reported in the Doğantepe forest water-1, ~38.17 mg/L, and the minimum concentration is found in the Doğantepe stream water, ~0.43 mg/L. Three water samples were within the permissible limit for WHO (2022) and TS 266 (2005).

High concentrations of Ca^{2+} and Na^+ in water affect soil properties, particularly soil particle dispersion, air and water permeability, structure, and porosity [33]. This situation results in undesirable environmental problems. Moreover, salt in drinking water poses several negative effects on health such as hypertension and kidney disease [34]. The concentrations of cations at the Doğantepe Forest Water-2 site exceed the limit values due to its proximity to the Siteler Organized Industrial Zone.

The mean concentrations of Ca^{2+} and Mg^{2+} in the forest water samples exceeded both the WHO 2022 and TS 266 2005 water quality criteria. All the groundwater samples are within the permissible limit for WHO (2022) and TS 266 (2005).

Mg^{2+}: Magnesium is the fifth most abundant element in seawater. Mg concentration in surface water occurs due to the weathering of rocks and is considered an important intake for all living organisms. The concentration varies with type of rocks, and it is found in the range of 1 mg/L to 100 mg/L. The maximum concentration of magnesium is found in the Doğantepe forest water-1, ~37.09 mg/L. The magnesium content of all water samples is below the maximum permissible limit of WHO 2022 and TS 266 (2005).

K^+: Among the ions responsible for salination, potassium is the lowest constituent. Potassium is mainly from the result chemical decomposition of several minerals such as sylvite and carnallite. Potassium content in natural water resources is far lower than that of sodium content because of potassium bearing rocks weathering rates is slower than those of sodium. Potassium is added to water through sewage discharge, industrial discharge and the use of fertilizer.

The following crescent order of cation toxicity is observed: $K^+ < Na^+ < Mg^{2+} < Ca^{2+}$. Correlating with WHO (2022) and TS 266 (2005) guideline values for drinking water and public health, it may be concluded that the water of the investigated area is not found to be suitable for all drinking and domestic purposes.

Quantification of metal levels

Analysis results of nineteen heavy metals (lead, zinc, chromium, manganese, vanadium, copper, cadmium, cobalt, nickel, aluminum, mercury, arsenic, antimony, selenium, boron, beryllium, silver, barium and thallium) are listed in Table 3.

Metal (µg/L)	Doğantepe stream water	Doğantepe forest water -1	Doğantepe forest water -2	WHO (2022)	TS 266 (2005)
Al	2.319017	32.435801	428.547214	200	200
As	0.029960	2.693684	2.037816	10	10
Ag	<0.000	0.191205	<0.000	100	No guideline
B	0.765158	104.699756	113.485921	2400	1000
Be	<0.000	<0.000	<0.000	No guideline	No guideline
Cd	<0.000	<0.000	<0.000	3	5
Co	<0.000	<0.000	0.278600	No guideline	2000
Cr	0.106366	3.655338	34.224172	50	50
Cu	0.064859	0.149065	2.102968	2000	2000
Fe	0.839795	46.522454	218.893606	No guideline	300
Hg	<0.000	0.023571	0.007688	6	1
Mn	<0.000	0.767010	1.338832	200	50
Ni	0.031252	2.564760	2.273995	20	20
Pb	<0.000	<0.000	<0.000	10	10
Sb	<0.000	<0.000	<0.000	20	No guideline
Se	<0.000	<0.000	0.326248	40	40
Tl	<0.000	<0.000	<0.000	No guideline	No guideline
V	0.050982	16.416220	4.717240	No guideline	No guideline
Zn	3.992487	6.219836	759.751530	No guideline	200

Table 3. Metal concentrations (µg/L) and variations in three sites and comparison with WHO and TS 266 standards

Among the heavy metals analyzed, Ag, Be, Cd, Co, Mn, Hg, Pb, Sb, Se, and Tl concentrations were below detection limits in the Doğantepe stream water. Similarly, heavy metals of Be, Cd, Co, Pb, Sb, Se, and Tl were below detection limits in the Doğantepe forest water-1 samples, and Be, Cd, Pb, Sb, and Tl were below detection limits in the Doğantepe forest water-2 samples. Heavy metals of Al, Cr, Cu, Fe, and Zn concentrations measured at the Doğantepe forest water-2 sampling site exceed the limit levels compared to the other sites. This is likely due to its proximity to the Siteler Organized Industrial Zone. On the other hand, concentrations of Al, B, Fe, and Zn were high at all sites. Iron, boron, and aluminum are among the most abundant elements in the Earth's crust, and aluminum is naturally present in spring waters due to the dissolution of minerals by acidic waters. Therefore, the sources of Fe and Al can be attributed to natural causes. In our study the concentration of Al ranges from is ~ 2 to ~ 428 mg/L. Limit value for aluminum prescribed by TS 266 is 200 mg/L [23]. The relatively high concentrations of aluminum can cause Alzheimer disease in human. Zinc is not commonly found in nature. Zinc is released into the environment via industrial activities such as metal mining, waste burning, and steel manufacturing. Zinc is released into the environment via industrial activities such as metal mining, waste burning, and steel manufacturing**.** In our study the concentration of Zn ranges from ~ 3,9 to ~ 769 mg/L. The relatively high concentration of Zn is likely due to the proximity of the sampled sites to the industrial zone.

In water, Doğantepe stream water concentrations were: zinc> aluminum> iron> boron> chromium> copper> vanadium> nickel> arsenic> silver = beryllium = cadmium = cobalt = mercury = manganese = lead = antimony = selenium = thallium. In water, Doğantepe forest water-1 water concentration were: boron> iron> aluminum> vanadium> zinc> chromium> arsenic> nickel> manganase> silver> copper> beryllium = cadmium = cobalt = antimony = lead = selenium = thallium. In water, Doğantepe forest water-2 water concentration were: zinc> aluminum> iron> boron > chromium> vanadium > nickel > copper> arsenic> manganese> selenium > cobalt > silver = beryllium = cadmium = antimony = lead = thallium. The surface waters of Doğantepe stream water, Doğantepe forest water-1, Doğantepe forest water-2 can be classified as 1st class water, 2 nd class water, 4 th class water, respectively, according to the WHO (2022) and TS 266 (2005) criterias.

Heavy metal pollution index (HPI)

The calculations of HPI for each heavy metal with unit weightage (Wi) and highest permissive value (Si) as obtained in the presented study were detailed Table 4-6. HPI was calculated using WHO standard and the following data was observed for the three sites.

Metal (µg/L)	Doğantepe stream water (C_i)	Standard permissible value (Si)	Weightage ($W_i = 1/S_i$)	Sub-index (Q_i)	$W_i \times Q_i$
Al	2.319017	200	0.0050	1.159508	0.005797
As	0.029960	10	0.100	0.299609	0.029960
Ag	<0.000	100	-	-	-
B	0.765158	2400	0.000416	0.031881	1.32x10^{-4}
Be	<0.000	No guideline	-	-	-
Cd	<0.000	3	-	-	-
Co	<0.000	No guideline	-	-	-
Cr	0.106366	50	0.0200	0.212733	0.004254
Cu	0.064859	2000	0.0005	0.003242	1.6x10^{-6}
Fe	0.839795	No guideline	-	-	-
Hg	<0.000	6	-	-	-
Mn	<0.000	200	-	-	-
Ni	0.031252	70	0.01428	0.0446467990	6.6x10^{-4}
Pb	<0.000	10	-	-	-
Sb	<0.000	20	-	-	-
Se	<0.000	40	-	-	-
Tl	<0.000	No guideline	-	-	-
V	0.050982	No guideline	-	-	-
Zn	3.992487	No guideline	-	-	-
$\sum W_i$: 0.140196	**$\sum W_i \times Q_i$:** 0.040806	**Mean HPI:** 0.291068			

Table 4. Mean HPI of Doğantepe stream water

Metal (µg/L)	Doğantepe stream water (C_i)	Standard permissible value (Si)	Weightage ($W_i = 1/S_i$)	Sub-index (Q_i)	$W_i \times Q_i$
Al	2.319017	200	0.0050	1.159508	0.005797
As	0.029960	10	0.100	0.299609	0.029960
Ag	<0.000	100	-	-	-
B	0.765158	2400	0.000416	0.031881	1.32x10^{-4}
Be	<0.000	No guideline	-	-	-
Cd	<0.000	3	-	-	-
Co	<0.000	No guideline	-	-	-
Cr	0.106366	50	0.0200	0.212733	0.004254
Cu	0.064859	2000	0.0005	0.003242	1.6x10^{-6}
Fe	0.839795	No guideline	-	-	-
Hg	<0.000	6	-	-	-
Mn	<0.000	200	-	-	-

Ni	0.031252	70	0.01428	0.044646	$6.6x10^{-4}$
Pb	<0.000	10	-	-	-
Sb	<0.000	20	-	-	-
Se	<0.000	40	-	-	-
Tl	<0.000	No guideline	-	-	-
V	0.050982	No guideline	-	-	-
Zn	3.992487	No guideline	-	-	-
∑W_i: 0.140196	**∑ W_i × Q_i:** 0.040806	**Mean HPI:** 0.291068			

Table 5. Mean HPI of Doğantepe forest region-1 water

Metal (µg/L)	**Doğantepe forest water-2 concentration (C_i)**	**Standard permissible value (S_i)**	**Weightage (W_i = 1/S_i)**	**Sub-index (Q_i)**	**W_i × Q_i**
Al	428.547214	200	0.0050	214.273607	1.071368
As	2.037816	10	0.100	20.378169	2.037816
Ag	0.017007	100	-	-	-
B	113.485921	2400	0.000416	4.728580	0.001967
Be	<0.000	No guideline	-	-	-
Cd	<0.000	3	-	-	-
Co	0.278600	No guideline	-	-	-
Cr	34.224172	50	0.0200	0.684483	0.013689
Cu	2.102968	2000	0.0005	0.105148	$5.2x10^{-5}$
Fe	218.893606	No guideline	-	-	-
Hg	0.007688	6	0.1666	0.128139	0.021347
Mn	1.338832	200	0.0050	0.0066	$3.3x10^{-5}$
Ni	2.2739951	70	0.01428	0.0324850897	0.000463
Pb	<0.000	10	-	-	-
Sb	<0.000	0.005	-	-	-
Se	0.326248	40	0.025	0.815620	0.020390
Tl	<0.000	No guideline	-	-	-
V	4.717240	No guideline	-	-	-
Zn	759.751530	No guideline	-	-	-
∑Wi: 0.27613	**∑ Wi × Qi:** 3.167129	**Mean HPI:** 11.469703			

Table 6. Mean HPI of Doğantepe forest region-2 water

The HPI values of the present study indicate that the water samples from the stream and forest site are not critically contaminated with respect to heavy metals. The Doğantepe forest water-2's location near the industry areas, can contribute to pollution in forest water-2, which explains why sampling location has the highest HPI value (11.4697).

V. CONCLUSION

Heavy metal pollutants and salinity have been a serious environmental concern in aquatic ecosystems.

The present study highlights that the water quality of Doğantepe stream and forest water samples, located in Altındağ, Ankara,Türkiye. The results show that sodium and calcium are the predominant soluble ions in the study region. The salinization of Doğantepe forest water-2 sample is generally found in high levels in comparison with the other sites.

This study also examines 19 heavy metals in the surface samples of the Doğantepe stream and forest water. According to the results of the chemical analysis, the elements were ordered in terms of their excess values: Doğantepe stream water: zinc> aluminum> iron> boron> chromium> copper> vanadium> nickel> arsenic> silver = beryllium = cadmium = cobalt = mercury = manganese = lead = antimony = selenium = thallium. Doğantepe forest water-1: boron> iron> aluminum> vanadium> zinc> chromium> arsenic> nickel> manganase> silver> copper> beryllium = cadmium = cobalt = antimony = lead = selenium = thallium. Doğantepe forest water-2 water: zinc> aluminum> iron> boron > chromium> vanadium > nickel > copper> arsenic> manganese> selenium > cobalt > silver = beryllium = cadmium = antimony = lead = thallium. According to the WHO (2022) and TS 266 (2005) criteria's, the surface water of Doğantepe stream water, Doğantepe forest water-1, Doğantepe forest water-2 were classified as 1st class water, 2nd class water, 4th class water, respectively.

Samples collected from Doğantepe evidence the slightly significant metal concentration in water samples. In all samples, common heavy metal contaminants include aliminum, boron, silver, and zinc. This is attributed to the industrial area located near the sampling sites.

Assessing heavy metal pollution through indices HPI, the heavy metal pollution index values are found as low class. This indicates that the water poses no health risks for either adults or children.

The obtained data suggest that the metal concentration levels in the sampled waters comply with water quality regulations. Thus, the water from these sources is deemed suitable for agricultural and livestock purposes.

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