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Some air and water pollution indicators in and around the Lake Abant, Turkey

Abant Gölü (Türkiye) ve çevresinde hava ve su kirliliği göstergeleri

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Abstract

In this paper was discussed some implications of landuse induced pollution around Lake Abant, Turkey, on the00000 basis of field observations and some analytical data. The extent of air and water pollution was considered using inductively coupled plasma atomic emission spectrometry (ICP-AES) and ion chromatography analyses. The ICP-AES results obtained from lichen *Xanthoria parietina* implied the existence of heavy metal accumulation (Fe>Al>Mn>Ba>Zn>Pb>Ni>Cu>Cr>B>Co>Cd), caused possibly by traffic load in the study area. Lake waters seem to reach to a considerable extent. Howbeit, air and water pollution form a potential risk for the lake environment in case human load by recreation and tourism activities continue. Thus, pollution-prevention precautions should be taken for sustainable use of the lake.

Keywords: Pollution, landuse, heavy metal concentration, ICP-AES, ion chromatography, Lake Abant (Turkey).

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Introduction

Turkey has more than one hundred lakes comprising about 12 % of the mainland having a surface area of 9244 km^2. Most of lakes are clustered in the region of lakes (Göller Yöresi in Turkish). The lake environments, particularly those surrounded by forest lands, are one of the most preferred places where recreational and tourism activities are carried out in both summer and winter seasons.

The Black Sea region of Turkey, which is well-known with its natural, historical and cultural diversities, comprises dense forest lands, wild life, natural lakes, thermal springs and waterfalls, has also a few natural lakes, allowing a wide range of alternative tourism activities (Yazıcı and Cin 1997). In the western part of the region, Lake Abant is the most preferred site for both recreational and tourism purposes. Owing to its wide range of natural beauties and plant communities, such as several species of *Fagus*, *Quercus*, *Pinus*, *Salix*, *Juniperus*, *Corylus* and *Rhododendron*, the lake was incorporated into the list of the natural parks of Turkey on 21 October 1988. The Abant Natural Park has an area of 1196.5 ha since 1991 (Dügel et al. 2008). In addition, several species of fish are available in the lake, such as *Salmo trutta abanticus*, *Leuciscus cephalus* and *Barbel capito* (Altındağ 1999). Dügel et al. (2008), however, reported the existence of 7 fish species in the lake. In this paper, we aim to explain our preliminary results regarding air and water pollution in the studied lake using inductively coupled plasma atomic emission spectrometry (ICP-AES) and ion chromatography analyses.

Study area

Turkey has a wide range of morphological elements, which reflect the properties of the area they are found in. One can find such elements with different sizes and properties along the North Anatolian Fault. These areas are used for residential, agricultural and touristic purposes. Lakes brighten the surrounding area and contribute to the economic and social life (Özgüç 2003) and water has been of utmost importance for human and will be much more in the future. It is one of the most significant life resources. Innumerable conflicts have broken out just to gain the dominance over the water resources. In the face of increasing global population, the need for water will be increase, so will the importance of every drop. Short of water might come to mean that the next generations will suffer from serious problems not only related to water but also daily life.

Lake Abant lies between the latitudes 40° 36' 45" - 40° 35' 55" north and longitudes 31° 16' 18" - 31° 17' 34" east in the Black Sea region of Turkey. This fresh-water lake is one of the important (1.28 km^2) natural reservoirs in the northwest Black Sea region of Turkey and is located at 1298 above sea level 34 km southwest of the city of Bolu (Figure 1a). The lake is found in the Abant range is within the borders of the town Mudurnu. The lake was formed as result of drainage disruption by a landslide (Erinc et al. 1961) and is located in a tectonic depression (Lahn 1948), controlled by the North Anatolian Fault (Neugebauer et al. 1997). Feeding by spring waters, the lake has a maximum depth of 45 m. It is surrounded by high mountains (Mt. Abant 1748) and has abundant supplies of fresh water by the discharging rivers, the biggest of which is the Beşpoyra Stream. However, runoffs discharging into the lake causes alluviation.

Due to the favorable climatic conditions, the area has a rich vegetation species, such as beech tree, oak, pine, poplar, willow, juniper, nut tree and forest rose. The overgrowth of some plant species at the bottom of the lake is believed to be detrimental to the biological life. From this point of view, the places are called turbary where semi-humidified organic materials accumulate in the water and the vegetation is poor in trees and endemic plants. It can be observed that turbaries form where environmental conditions are favorable for water and marsh plants. They cause any lake where they are dominant to shrink over time.

According to data obtained from Turkish State Meteorological Service (TSMS), the area receives a total precipitation of 652.4 mm. Maximum and minimum precipitations occur in January (117.6 mm) and November (13.1 mm), respectively. The average air temperature is 10.7 °C. The hottest month is July with the average of 18.9 °C. However, temperatures decline down to 1.2 °C in January. Winds from W, SW and NE are prevailing.

The Black Sea region can be an alternative tourism center with its historical, natural, and cultural values (Yazıcı and Cin 1997). The lake found in the Abant range is within the borders of the town Mudurnu. It is 1.333 m high above the sea level and also 34 km away from the city center, 225 km from Ankara and 258 km from Istanbul. Its surface area measures 1.26 km^2. The Lake Abant was proclaimed to be a Natural Park on 21 October 1988. When previous studies are summarized, it can be seen that it used to cover more area than it does today.

The vegetation is very rich thanks to the climate. Among the examples are beech tree, oak, pine, poplar, willow, juniper, nut tree, forest rose and various water plants. The overgrowth of some plant species at the bottom of the lake is believed to be detrimental to the biological life. From this point of view, the places are called turbary where semi-humidified organic materials accumulate in the water and the vegetation is poor in trees and endemic plants. It can be observed that turbaries form where environmental conditions are favorable for water and marsh plants (Mater and Sunay 1985). They cause any lake where they are dominant to shrink over time.

Touristic activities around the lake started in 1960s and in Bolu, the first accomodation facility was built around the Lake Abant (Taşlıgil 1999). Then these activities increased between 1985 and 2000 and have recently become more intense. 108276 domestic and 22714 foreign tourists were hosted in two hotels. The numbers of the tourists taking daily tours to the Lake Abant were 180189 in 2000, 249616 in 2005 and 340412 in 2008 according to data from Provincial Agriculture Directorate of Bolu. The lake freezes in winter and takes a breathtaking form in spring and a marvelous beauty in fall. Lakes contribute to the development of tourism. The amount of the touristic lakes is high. The other lakes are Gölcük, Karamurat, Çubuk, Sülük, Sünnet, Karagöl, Efteni and Yedigöller. The Lake Abant, our study area, is a prominent one.

It is always possible to do sportive activities, walking, camping, fishing and riding by the lake. A road of 7.4 km surrounds the lake via which one can go to any place around the lake. Moreover, there are facilities along the Abant-Bolu highway such as hotels, taverns, do-it-yourself camps. Recreational activities apart from these facilities also pollute the lake and give damage to the surrounding flora. The asphalt road passing by the lake adversely affects the lake and its environ. Accordingly, smoke released by the vehicles is also detrimental to the lake. It has been realized since the second half of the 19th century that man has a significant role in shaping the environment. Deforestation, decrease in the level of the lake and changes in landuse (Efe 1995) are important indicators of the disturbance of the lake's natural structure. To avoid such negative outcomes, The Lake Abant and its environ were proclaimed Natural Park. Heed should be paid to preserve the park, where construction is prohibited or seldom allowed following a meticulous procedure. Previous studies confirmed that illegal permissions were granted to some privileged individuals. These buildings are called "plateau villas", which have negative impacts on the lake. The park has lost some of its characteristics as a result of such illegal permissions.

Settlement is not dense around the lake. On the other side, daily tours taken to the area have lately increased. Therefore, effective and sustainable precautions should be taken to avoid the dangers that could be posed by such daily flows. As the pollution level increased in the area, the population of the Abant trout accordingly decreased. The number of the guests at hotels by the lake has also increased; so has the pollution. A reliable infrastructure should be constructed and preserved, and sewers and waste water drains should be ameliorated to avoid probable outbreaks of leakage. The visitors coming for recreational purposes should pay attention not to pollute the area. Of course, everybody has the right to make use of the area, but without harming it.

Every touristic activity is meaningful for the local people because it financially contributes to the area. The trips taken to the area are the most important income sources in Abant, which elevate the economic welfare of the local people. Further, the touristic activities going around in Abant provides employment, as well.

On condition that aforesaid measures are heedfully, painstakingly and sustainably adopted in the area, the lake can reclaim its lost properties.

Material and Methods

Operating conditions and instrumentation

Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP-AES Varian Liberty II Sequential Series-Axial, Australia) was used for to determination of elements (Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn) in lichen samples (*Xantoria* sp.). This equipment was used with Intel Pentium IV PC and Liberty ICP-Expert Sequential (version: v.30) software. The concentrations of Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn were measured at 396.152, 249.773, 455.403, 317.933, 226.502, 228.616, 267.716, 324.754, 259.940, 766.490, 279.553, 257.610, 589.592, 221.647, 220.353, and 213.856 nm wavelengths, respectively. The equipment was calibrated with using ICP multi-element Standard solution VIII (Merck, 24 elements) at 0.1, 1.00, 10.00 and 50.00 mg/l in four dotted measures. Three replicates were done for each measurement and then standard means were calculated. pH, conductivity, total dissolved solids (TDS) and salinity of the water samples were measured with Consort-C864 (Belgium) multi pH-meter. Ion chromatography (Shimadzu, Japan) was used for the determination of anion and cation (F^-, Cl^-, NO_2^-, Br^-, NO_3^{-3}, PO_4^{-3}, SO_4^{-2} and NH_4^+) in the water samples. This equipment used was: LC-20AD SP pump, SIL- 10AP Auto sampler, SCL-10A vp system controller, CDD-10A sp conductivity detector, CTO-20AC sp column oven and LC solution (version: 1.23 sp1) software. The equipment was calibrated with Shimadzu anion (P/N 228-33603-93) and cation (P/N 228-33603-94) standard solution in four dotted measures at different concentrations. Three replicates were done for each measurement and then standard means were calculated.

Element and heavy metal analysis

The sample (0.5 g wet weight) was weighed in a Kjeldahl flask. 10 ml nitric acid was added and was heated to 100 ^oC for 2 h. 5 ml hydrochloric (37 %) acid and 0.5 ml sulfuric acid were added and the flask was heated (120 ^oC) until no white smoke was emitted. The residue was dissolved in 2 % nitric acid and transferred into a volumetric flask. This procedure was repeated three times for every sample. This solution was put into the ICP-AES apparatus sample tubes and spectroscopic measurement was made under optimum instrumental parameters (Table 1). The minerals (Na, K, Ca, Mg,) and heavy metals (Al, Cd, Co, Cr, Mn, Ni, Pb, Zn, Cu, Mn and Fe) were measured by using ICP-AES and then concentrations obtained were calculated based on standard deviation after making three replicates treated for every sample.

Results and Discussion

Tourism and landuse change

Figure 1 shows the distribution of landuse units in the lake area, including swamps and mosses and natural vegetation cover. There is a qualified 7.4 km long roadway throughout the lake coast, making accessible to visit all coasts. The onset of eutrophication seems to be the most serious threat on the lake coast since early 1985 (Mater and Sunay 1985) and now at more increased rate at developed through the west, northeast and south coasts of the lake because of natural and cultural reasons. The northwest, southwest and northeast parts of the lake are also most seriously exposed to deforestation. Due to the construction of hotels, a considerable forest land was lost and air pollution reached a significant extent with the increase in the number of visitors.

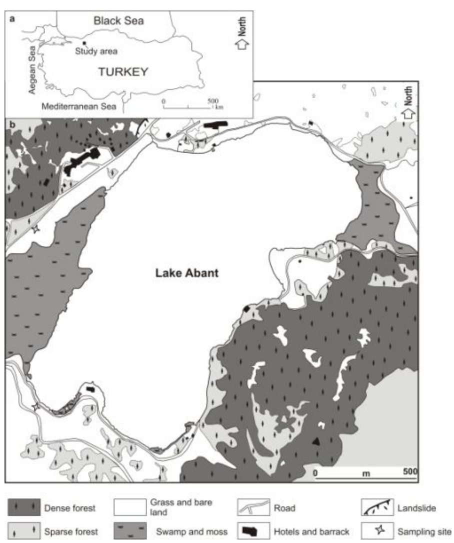


Figure 1. Location (a) and land-use map of the study area.

According to official reports obtained from the Bolu Directorate of Tourism, tourism activities commenced in early 1960’s with the construction of Kiosk to the south of the lake. The main growth, however, occurred between 1985 and continues at present. The number of one-day trip visitors in 2000, 2005 and 2008 were 180189, 249616 and 340412, respectively, showing the increase of about 90 % in the last eight years. The need for tourist accommodation is, however, fulfilled by two hotels with high accommodation capacity and facilities, Abant Palace and Büyük Abant Hotel, belonging to the Taksim International Group. In 2008, the number of native and foreign fellows was 108276 and 22714, respectively. These official figures reveal that the lake attracts the attention of people for both one-day recreation and diurnal tourism activities. Considering that transportation can only be carried out by motor vehicles, a change occurred in air quality in the lake environment as well as in the lake waters caused by the human interference, which is discussed below. Geographical coordinates, elevation values and areal attributes of some lakes at this region were showed in Table 1.

Table 1. Modified from Taşdemir A. (2008)

Lake	Geographical Coordinates		Elevation (m)	Area (km^2)
Poyrazlar	40°50' N	30°27' E	20	0.60
Küçük Ak	40°52' N	30°26' E	15	0.20
Taşkısığı	40°52' N	30°24' E	15	0.90
Büyük Ak	41°01' N	30°33' E	10	3.5
Acarlar	41°06' N	30°37' E	5	15.62
Melen	40°46' N	31°02' E	118	~10
Abant	40°35' N	31°17' E	1325	1.25
Gölcük	40°39' N	31°37' E	1080	0.05
Yeniçağa	40°46' N	32°01' E	990	3.85
Karamurat	40°33' N	30°57' E	700	0.05
Sülük	40°31' N	30°52' E	1070	0.60
Çubuk	40°28' N	30°49' E	750	0.20
Sünnet	40°25' N	30°57' E	1030	0.18

Instrumentation and calibration

Inductively Coupled Plasma–Atomic Emission Spectrometry (ICP-AES) was used for defining elements (Al, B, Ba, Ca, Cd, Co, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb and Zn) detected within lichen (*Xantoria* sp.) and water samples. The equipment was calibrated with using ICP multi-element Standard solution VIII (Merck, 24 elements) at 0.1, 1.00, 10.00 and 50.00 mg/L in four dotted measures. Three replicates were done for each measurement and then standard means were calculated. Calibration parameters for ICP-AES were shown in Table 2. Calibration Curve and Intensity Spectrum of elements used for ICP-AES were showed in Figure 3-4.

Table 2. Calibration parameters for ICP-AES (unit, mg/l; R^2: 0.999).

Element	Wavelength (nm)	Standards				Curve Type	Equation
Al	396.152	0.10	1.00	10.00	50.00	Linear	y = 6862.88 x + -18.66
B	249.773	0.10	1.00	10.00	50.00	Linear	y = 5025.5 x + 466.80
Ba	455.403	0.10	1.00	10.00	50.00	Linear	$y = 2{,}71934*10^6$ x + 14888.7
Ca	422.673	0.10	1.00	10.00	50.00	Linear	y = 22429.7 x + 618.19
Cd	226.502	0.10	1.00	10.00	50.00	Linear	y = 14596.6 x + 406.20
Co	228.616	0.10	1.00	10.00	50.00	Linear	y = 6785.89 x + 111.90
Cr	267.716	0.10	1.00	10.00	50.00	Linear	y = 15986.5 x + 326.62
Cu	324.754	0.10	1.00	10.00	50.00	Linear	y = 47466.4 x + 463.62
Fe	259.940	0.10	1.00	10.00	50.00	Linear	y = 21148 x + 576.71
K	766.490	0.10	1.00	10.00	50.00	Linear	y = 28651.2 x + -3829.09
Mg	279.553	0.10	1.00	10.00	50.00	Linear	y = 422751 x + 62212.80
Mn	257.610	0.10	1.00	10.00	50.00	Linear	y = 95170 x + 3233.49
Na	589.592	0.10	1.00	10.00	50.00	Linear	y = 387397 x + -2485.47
Ni	221.647	0.10	1.00	10.00	50.00	Linear	y = 1924.89 x + 49.64
Pb	220.353	0.10	1.00	10.00	50.00	Linear	y = 943.094 x + 45.17
Zn	213.856	0.10	1.00	10.00	50.00	Linear	y = 13298.7 x + 395.08

IC was used for defining anion and cation contents (F^-, Cl^-, NO_2^-, Br^-, NO_3^{-3}, PO_4^{-3}, SO_4^{-2} and NH_4^+) within the water samples. The equipment was calibrated at different concentrations using Shimadzu anion (P/N 228-33603-93) and cation (P/N 228-33603-94) standard solutions in four dotted measures. Three replicates were performed for each measurement and then standard means were calculated. Calibration parameters for IC were shown in Table 3.

Table 3. Calibration parameters used for IC analyses (unit, mg/l)

Element	Standards				Retention Time (min)	Curve Type	Equation	R^2
F	0.05	0.5	2.5	5.00	4.08	Linear	y = 1.80e-005 x + 7.58e-002	0.999
Cl	0.10	1.00	5.00	10.00	5.36	Linear	y = 2.50e-005 x + 0.18	0.999
NO_2^-	0.15	1.50	7.25	15.00	6.01	Linear	y = 4.75e-005 x + 0.31	0.998
NO_3^-	0.10	1.00	5.00	10.00	7.02	Linear	y = 6.48e-005 x + 0.14	0.997
Br	0.30	3.00	15.00	30.00	7.68	Linear	y = 4.46e-005 x + 0.66	0.999
PO_4^{-3}	0.30	3.00	15.00	30.00	13.41	Linear	y = 9.97e-005 x + 0.46	0.999
SO_4^{-2}	0.40	4.00	20.00	40.00	15.68	Linear	y = 3.37e-005 x + 0.25	0.998
NH_4^+	0.20	0.50	1.00	2.00	4.05	Linear	y = 13298.7 x + 395.08	0.997

Chromatography spectrum and retention times of F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{-3} and SO_4^{-2} using IC was shown in Figure 2.

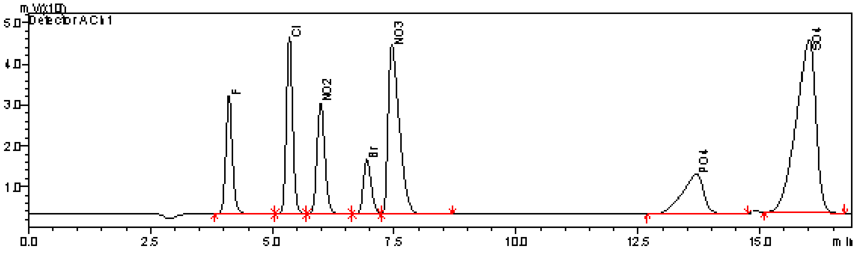
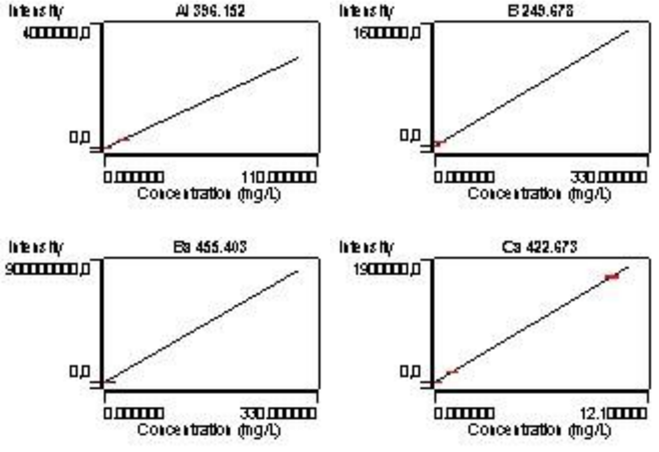
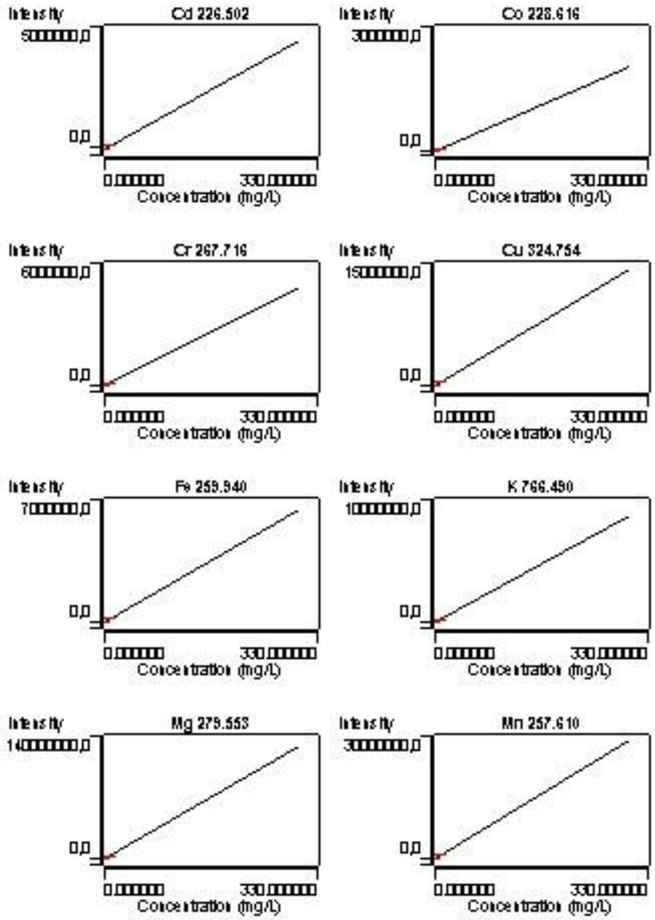


Figure 2. Anion spectrum obtained from IC




Intensity
Cd 226.502
Co 228.616
Cr 267.716
Cu 324.754
Fe 259.940
K 766.490
Mg 279.553
Mn 257.610
0,0
Concentration (mg/L)

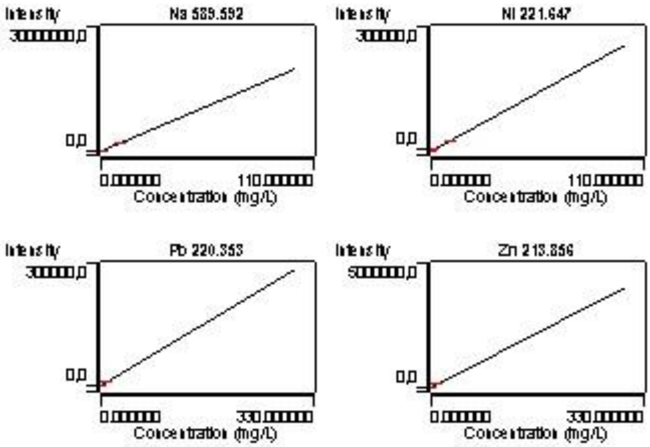
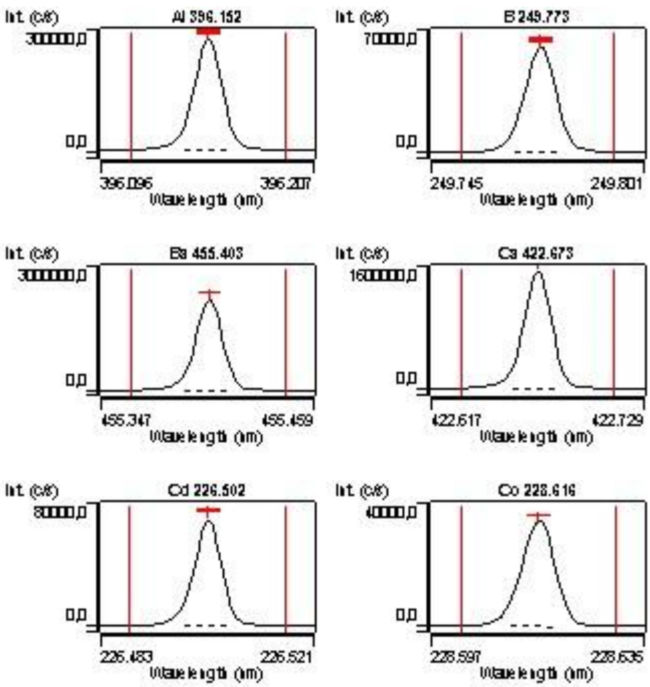


Figure 3. Calibration curves of elements used for ICP-AES analyses



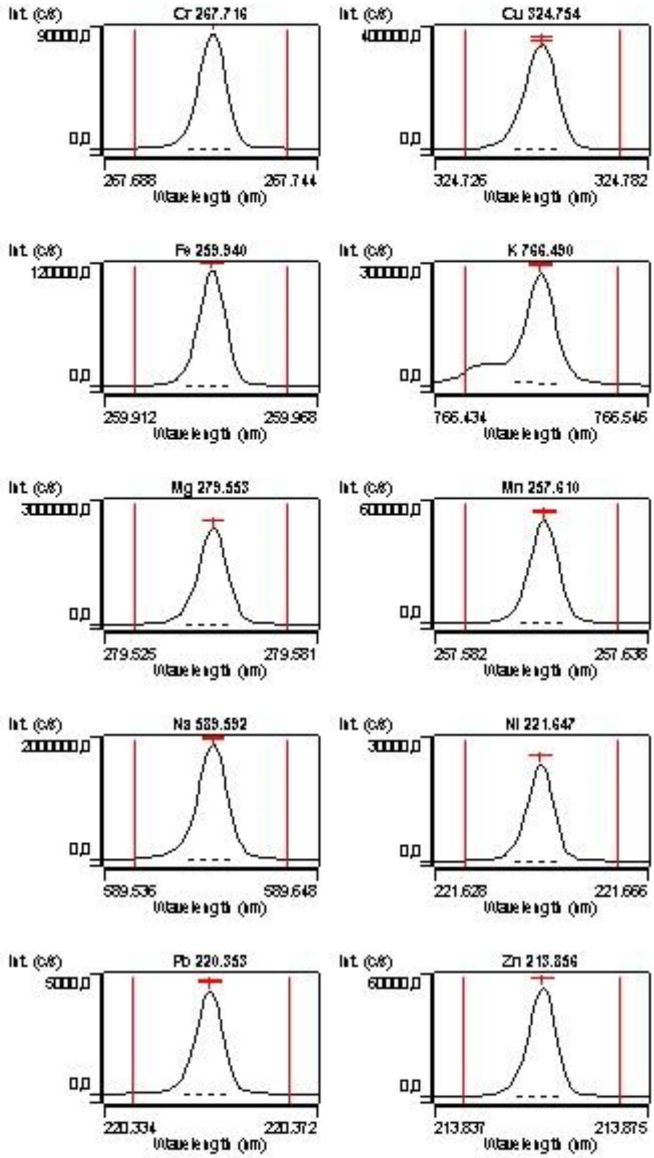


Figure 4. Intensity spectrums of elements used for ICP-AES analyses

Lichens as pollution indicators

Lichens, symbiotic organisms, including fungus and algae, are bioindicators giving reliable information on air pollution as they easily absorb various pollutants, such as SO_2 and NO_2 released from fuel oil combustion and exhaust of motor vehicles, acid rains from the burning of fossil fuels, and dangerous toxic heavy metals (Cd, As, Pb, Cr, Zn, Ni, Sn, Cu etc.) from different sources. The significance of lichens as bioindicators of air pollution is a well-known fact since the second half of the 19 century (Nylander 1866). Several aspect of lichens as bioindicators were reviewed by Skye (1979), Conti and Cecchetti (2001), and also explained in text books (Ferry et al. 1973). Recently, the attention paid to the lichen-based pollution in Turkey increased and several papers were published (John 1989, Sommerfelt and John 2001). In the study area, limited number of lichen studies was carried out by (Karamanoğlu 1971, Aydın 1990, Çobanoğlu and Akdemir 2004).

For ICP-AES analyses, we collected Xanthoria samples, which are represented by the abundant presence of *Xanthoria elegans* (Link), *Xanthoria fulva* (Hoffm), *Xanthoria parietina* (L.) and *Xanthoria polycarpa* (Hoffm.) throughout the lake area Çobanoğlu and Akdemir (2004) from surfaces of beech trees near the lake coast. Table 4 and 5 show the results of non-heavy metals and heavy metals identified within the samples of *Xanthoria parietina*, respectively. Based on the results in Table 1, Ca was determined to be of considerable amount with the average of 78.63 %, which is followed by K (av: 12.31 %), Mg (av: 7.77 %) and Na (av: 1.91 %).

Table 4. Other main elements (non-heavy metals) obtained from ICP-AES analyses of lichens

Elements ($\mu g/g^{-1}$ dry wt)	Lake Abant (W coast) E-facing tree surface	Lake Abant (S coast) NW-facing tree surface
Ca	8822.41±8.6	18383.7±15.3
K	1753.56±7.4	2237.93±7.7
Mg	1174.46±5.6	1283.43±5.8
Na	242.986±2.3	408.755±3.1

Table 5. Heavy metal concentrations obtained from ICP-AES analyses of lichens

Heavy metals	Lake Abant (W coast) E-facing tree surface (μgg^{-1} dry wt)	Lake Abant (S coast) NW-facing tree surface (μgg^{-1} dry wt)
Al	1510.14±4.73	962.569±3.41
B	7.82524±0.41	7.77764±0.39
Ba	47.5436±0.84	28.3075±0.75
Cd	0.681507±0.05	0.553179±0.03
Co	1.42519±0.14	1.05101±0.09
Cr	8.05881±0.33	7.86684±0.31
Cu	11.0962±0.47	11.0761±0.43
Fe	2338.05±5.64	1461.04±4.11
Mn	159.677±1.82	65.1046±1.01
Ni	11.8860±0.58	11.5578±0.55
Pb	13.3179±0.65	7.76361±0.48
Zn	39.0828±0.93	41.5491±0.97

Table 6. Comparison of the average heavy metal contents within some lichens in different localities elsewhere. Partly modified from Nayaka (2003) ($\mu g/g^{-1}$ dry wt)

Lichen species	Cr	Pb	Fe	Zn	Cu	References
Xanthoria parietina	8.05	13.31	2338	39.08	11.09	This work
C. candelaris (L.) Laundon	5.18	ND	7556	95.76	23.72	Nayaka 2003
D. consimilis (Stirton) Awasthi	35.59	149.15	7081	198.14	22.22	Nayaka 2003
P. leucosorodes Nyl.	3.04	31.92	570	79.86	5.84	Nayaka 2003
P. nanospora (A. Singh) Upreti	36.43	175.9	1506	231.01	18.28	Nayaka 2003
P. cocoes (Swartz) Nyl.	9.53	63.63	12056	103.3	16.3	Nayaka 2003
D. aegialita (Afz. in Ach.) Moore	34.57	46.4	6887	98.6	8.99	Nayaka 2003
C. candelaris (L.) Laundon	95.29	623.95	6926	157.496	19.75	Nayaka 2003
L. leprosa Fée	29.92	154	3121	128.15	9.84	Nayaka 2003
P. petricola Nyl. In Crombie	19	83.33	9202	133.05	115.19	Nayaka 2003
P. petricola Nyl. in Crombie	18.47	101.4	5538	105.38	338.12	Nayaka 2003
B. isidiza (Nyl.) Hale	12.99	22.05	22721	102.73	86.02	Nayaka 2003

Heavy metals yield, however, a more complicated composition. A comparison between the western and southern parts of the lake show that the concentrations of Cr (12.2 %), B (12.06 %), Pb (12.04 %), Mn (10.01%), and Zn (6.44 %) are higher quantity on the northwest facing surfaces of trees on the south coast. However, on the western coast, which is close to the hotels area and recreation place assigned for the daily visitors, Fe, Ba and Al show a conspicuous increase with the proportions of 33.72 %, 6.85 % and 21.68 % in the heavy metal contamination, respectively. Ni, Cu, Co, B and Cd were found, however, in close amounts within samples taken from the two sites. Thus heavy metal amount was identified as follows: Fe>Al>Mn>Ba>Zn>Pb>Ni>Cu>Cr>B>Co>Cd. These values reveal precipitation of various types of heavy metals in the study area, among which Fe and Al are in highest amounts, released commonly by automobile rusts or corrosion of auto body and tires or the input from soil particles etc. (Bargagli 1995-1998, Lu et al. 2008, Conti et al. 2009). In addition, the outstanding presence of other chemical elements, such as Ca, K, Mg and Na (Table) is also likely related to the contamination from soil particles in consequence of traffic load.

Water pollution parameters

In Turkey, fresh lakes used for drinking water, daily usage, fishing, tourism and recreation etc. are subject of pollution, causing serious ecosystem degradations, heavy metal accumulation (Akbulut et al. 2008, Akin 2009), eutrophication, and insomuch as growth in toxic cyanobacteria and microcystin concentrations dangerous for human health (Gurbuz et al. 2003). Several studies carried out on Turkish lakes showed the existence of phosphorus pollution caused by agricultural production (Atilgan et al. 2009) and data provided from the literature known suggest the predominance of human-induced affect of cultural eutrophication. Despite global warming and increasing need for water, pollution caused primarily by raw sewage is an ongoing and progressively increasing.

Owing to the presence of several natural beauties, the Lake Abant was predisposed to pollution as the result of human interference and a conspicuous reduction and peat accretion existed at various parts of the lake coast. This condition commenced in early 1985's (Mater and Sunay 1985) and continues today as confirmed by the abundance of *Chrysophyta* ve *Pryophyta* as biopollution indicators caused by contamination to the lake (Atıcı and Obalı 2002). To explain causes and level of water pollution in the lake, we investigated several physicochemical characteristics of the lake water, such as pH, conductivity, TDS, salinity, the constituents including F^-, Cl^-, NO_2^-, Br^-, NO_3^-, PO_4^{-3}, SO_4^{-2} and NH_4^+ and heavy metals collected from four parts (i.e. southwest, west, north and east) of the lake.

Table 7 shows that pH is very slightly alkaline throughout the lake coast. Atıcı et al. (Atıcı et al. 2005) measured pH levels throughout four different parts of the lake and found that it ranges between 8 (spring) and 8.6 (autumn). They also suggested that electrical conductivity values between 200 and 280 µmhos/cm confirming our data. In 2002, pH and conductivity were in average values of 8.05 and 221.5 µmhos/cm, respectively (Atıcı and Obalı 2002). Thus, there is a significant drop in pH degree of the lake waters, which is likely related either to acid rains or, more likely, to auto exhausts and sewer overflows increasing from day to day. In terms of dissolved solids, the lake waters contain an amount of 150 mg/l, which suggests contamination from wastewaters. The detected values of conductivity, TDS and salinity are, however, at desirable levels.

Table 7. Amounts of pH, conductivity, TDS and salinity for water samples

Sampling location	pH	Conductivity (µS/cm)	TDS (mg/L)	SAL (g/L)
Southwest coast	7.13±0.11	254±3.36	150±1.22	0.1
Northwest coast	7.10±0.10	243±2.94	144±1.15	0.1
North coast	7.62±0.11	245±3.01	145±1.18	0.1
East coast	7.13±0.12	246±3.05	146±1.19	0.1
Northeast coast	7.23±0.13	296±3.88	176±1.34	0.2

As seen in Table 9, NO_2^-, Br^- and PO_4^{-3} were not detected within the samples. The other ions F^-, Cl^-, NO_2, Br^-, NO_3^{-3}, PO_4^{-3}, and NH_4^+ were also found at low amounts, suggesting that the lake waters are very far from the threshold levels (WHO 2004, EPA 2006). Sulphate concentration was found exceptionally higher in amount with the average of 3.14 mg/L, which is followed in proportion by Cl^- (average: 1.68 mg/l).

Table 8. pH, conductivity and salinity values obtained from several lakes located in the studied region

Year	Lake	pH	Conductivity (µS/cm)	SAL (g/L)
2009	* Abant	7.10 – 7.23	243 – 296	0.1 – 0.2
2002–2003	**Abant	6.99 - 6.47	209 – 225	0.1 – 0.1
2002–2003	**Küçük Ak	8.59 - 9.09	305-346	0.1 – 0.2
2002–2003	**Taşkısığı	7.43 - 7.99	595-631	0.3
2002–2003	**Büyük Ak	7.97 - 7.56	271-385	0.1 – 0.2
2002–2003	**Acarlar	6.44	522	0.3
2002–2003	** Melen	6.23	384	0.2
2002–2003	** Poyrazlar	6.22 - 7.95	241	0.1
2002–2003	** Gölcük	7.10 - 7.72	182 – 224	0.1 – 0.1
2002–2003	** Yeniçağa	8.38 - 7.72	411 – 482	0.2
2002–2003	** Karamurat	6.34 - 7.95	263 – 276	0.1
2002–2003	** Sülük	6.47 - 6.70	240 – 264	0.1
2002–2003	** Çubuk	7.32 - 6.66	167 – 176	0.1
2002–2003	** Sünnet	7.12 - 7.22	399 – 428	0.2

* This study
** From Taşdemir A. (2008)

Table 9. The determined ions F^-, Cl^-, NO_2^-, Br^-, NO_3^{-3}, PO_4^{-3}, SO_4^{-2} and NH_4^+ in water samples (µg/l).

Sampling location	F^-	Cl^-	NO_2^-	Br^-	NO_3^-	PO_4^{-3}	SO_4^{-2}	NH_4^+
Southwest coast	71±0.5	2.50±0.11	*N.D	*N.D	405±4.9	*N.D	4.284±0.07	147±3.8
Northwest coast	98±0.7	1.59±0.07	*N.D	*N.D	*N.D	*N.D	3.314±0.05	203±4.2
North coast	80±0.6	1.619±0.07	*N.D	*N.D	*N.D	*N.D	2.875±0.04	247±5.3
East coast	78±0.6	1.676±0.08	*N.D	*N.D	*N.D	*N.D	3.072±0.05	276±5.5
Northeast coast	84±0.7	1.030±0.05	*N.D	*N.D	*N.D	*N.D	2.183±0.03	316±5.9

*N.D., Not determined

The composition of chemical elements and heavy metals in the lake waters are shown in Table 10. Based on these results, it can be suggested that Ca is the predominant element in the lake water with the average amount of 45.54 mg/l), followed by magnesium (1.34 mg/l) and sodium (1.98 mg/l). Heavy metal analyses showed that none of the elements has an average of 0.1 mg/l, suggesting that lake water today do not contain heavy metals to cause a threat for daily usage and other purposes.

However, the increasing risk for water pollution in Lake Abant may be of significance for habitat preferences of other organisms like Ostracoda (Dügel et al. 2008). Furthermore, Çelekli et al. (2007) suggested, regarding water quality, the lake water as 'mezotrophic and closer to eutrophic' caused by human activities or implied increasing numbers of phytoplankton species when nutrient input is increased.

Table 10. The elements detected in water samples

Elements	Sampling locations				
	Southwest coast	Northwest coast	North coast	East coast	Northeast coast
Al (µg/L)	22.43±1.2	4.84±0.7	6.79±0.8	8.95±0.9	70.26±2.5
B (µg/L)	29.26±1.7	17.90±1.3	22.21±1.1	19.97±1.2	28.37±1.6
Ba (µg/L)	70.01±2.3	77.60±2.6	76.35±2.5	71.97±2.5	127.52±4.9
Cd (µg/L)	*N.D.	*N.D.	*N.D.	*N.D.	*N.D.
Co (µg/L)	*N.D.	*N.D.	*N.D.	*N.D.	*N.D.
Cr (µg/L)	*N.D.	*N.D.	*N.D.	*N.D.	*N.D.
Cu (µg/L)	24.21±1.3	18.55±1.1	20.19±1.1	21.75±1.2	21.58±1.1
Fe (µg/L)	34.60±2.7	43.01±2.9	34.11±2.2	34.72±2.4	503.46±7.5
Mn (µg/L)	7.90±0.8	12.81±1.1	6.88±0.8	*N.D.	28.43±1.8
Ni (µg/L)	*N.D.	*N.D.	*N.D.	*N.D.	*N.D.
Pb (µg/L)	24.80±2.2	21.18±1.9	N.D.	47.23±3.3	28.192.4
Zn (µg/L)	*N.D.	*N.D.	*N.D.	*N.D.	*N.D.
Ca (mg/L)	43.1987±1.41	42.8977±1.32	42.6751±1.36	42.9438±1.35	56.0225±1.87
K (mg/L)	0.699484±0.03	0.485481±0.02	0.541989±0.02	0.548475±0.02	0.343129±0.01
Mg (mg/L)	4.80696±0.27	4.78045±0.22	4.75478±0.22	4.74376±0.21	4.68811±0.18
Na (mg/L)	2.62818±0.16	1.77164±0.12	1.89267±0.13	1.91341±0.13	1.74363±0.12

*N.D., Not determined

Conclusions

We tried to perform a preliminary evaluation of air and water pollution parameters from lichen and water samples in and around Lake Abant, Turkey. Heavy metals retained by the lichen *Xanthoria parietina* are found in descending order of Fe>Al>Mn>Ba>Zn>Pb>Cu>B. The predominant elements Fe and Al are in considerable amounts and likely associated with the precipitation caused by corrosion of motor vehicles and input from soil particles by traffic load. Nevertheless, based on the several measured physico-chemical parameters of the water of the lake, pollution is at desirable level today. However, some precautions regarding wastewater treatment and traffic control may be needed in order to prevent pollution in the future, considering the progressively increasing load by recreation and tourism activities in the lake area.

Özet

Bu çalışmada Abant Gölü ve çevresinde arazi kullanımından kaynaklanan kirlilik konusu arazi gözlemleri ve bazı analitik verilere dayanılarak tartışıldı. Hava ve su kirliliğinin boyutu indüktif eşlenikli atomik emisyon spektrometrisi (ICP-AES) ve iyon kromotografisi (IC) analizleri ile incelendi. *Xanthoria parietina* türündeki likenin ICP-AES analizi sonuçları sahada muhtemelen trafik yükünden kaynaklanan ağır metal birikiminin varlığını (Fe>Al>Mn>Ba>Zn>Pb>Ni>Cu>Cr>B>Co>Cd) göstermektedir. Göl sularında da kirlilik riskli boyutlara ulaşmak üzeredir. Sonuç olarak rekreasyon ve turizm aktivitelerinin devamı halinde göl ortamında hava ve su kirliliği potansiyel bir risk olmaya devem edecektir. Bu nedenle gölün sürdürülebilir kullanımını sağlama açısından kirliliğin önlenmesi çalışmalarına ihtiyaç vardır.

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