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ORIGINAL ARTICLE

Hydrochemical and microbiological quality of groundwater in West Thrace Region of Turkey

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Abstract The aim of this study was to do a preliminary assessment of the hydrochemical and microbial groundwater quality of the West Thrace region. Forty samples of groundwater collected from Edirne (Site 1) to Gelibolu (Site 2) were assessed for their suitability for human consumption. As^{3-} was non-detectable in all the groundwater and Zn^{2+}, Pb^{2+}, F^{-}, Cu^{2+}, NH_4^{+}, Cn^{-} PO_4^{3-} and Cl^{-} were all below their respective European Union drinking water directive (EU-DWD) and Turkish food codex-drinking water directive (TFC-DWD). Maximum Acceptable Concentrations (MAC) Ni^{2+}, Pb^{2+}, Cd^{2+}, Mg^{2+}, Mn^{2+}, and Ca^{2+} levels were detected in upper maximum acceptable concentrations 77.5, 42.5, 35.0, 50.0, 50.0, and 32.5% of the groundwater samples, respectively. However, in terms of Cr^{3+}, Ni^{2+} and Pb^{2+}, the differences between groundwaters of Sites 1 and 2 were significant ($p < 0.05$). Eight water samples (20%) had HPC exceeding the EU and Turkish water directive limit 20 CFU (Colony Forming Unit)/ml in drinking water and the maximum bacteria count recorded was 44 CFU/ml. Total coliforms, thermotolerant coliforms, *E. coli*, *Enterococcus* spp., *Salmonella* sp., *Staphylococcus* spp. and *P. aeruginosa* were detected in 25, 17.5, 15, 47.5, 15, 27.5, and 15% of the groundwater samples, respectively. Furthermore, heavy metals and trace elements were found after chemical analyzes in most samples. The pollution of groundwater come from a variety of sources, Meric and Ergene rivers, including land application of agricultural chemicals and organics wastes, infiltration of irrigation water, septic tanks, and infiltration of effluent from sewage treatment plants, pits, lagoons and ponds used storage.

Keywords Groundwater · Water quality · Microbiology · Public health · Thrace region

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Introduction

Water is essential for life, but it also remains a most important vector of illness and infant mortality in many developing countries and even in industrialized countries, where the numbers of cases of infectious intestinal diseases continue to increase (Jones and Watkins 1985).

Groundwater represents an important source of drinking water and its quality is currently threatened by a combination of over-abstraction and chemical and microbiological contamination (Reid et al. 2003). Many national and international standards declare the quality of groundwater and drinking water to be in the same scale. (EU Directive 1998; Turkish Food Codex 2001; USEPA, 2004; WHO 1993)

Depending on the source, raw water may contain a wide variety of harmless heterotrophic microorganisms such as *Flavobacterium* spp., *Pseudomonas* spp., *Acinetobacter* spp., *Moraxella* spp., *Chromobacterium*, *Achromobacter* spp., *Alcaligenes* spp. as well as numerous unidentified or unidentifiable bacteria (Aksu and Vural 2004; ICMSF 1998; Kolbel-Boelke et al. 1988).

Traditionally, the microbiological quality of drinking water is assessed by monitoring for non-pathogenic bacteria of faecal origin (faecal indicator bacteria) (Aksu and Vural 2004; Hijnen et al. 2000; Rompre et al. 2002). The species *E. coli* and members of the genus *Enterococcus* are bacteria traditionally used as hygiene indicators, and methods for their detection are essential elements of drinking water regulations all over the world. In the recently adopted European Union drinking water directive (1998), only *E. coli* and *Enterococcus* spp. are defined as obligatory microbial parameters. Chemical parameters were also important for water quality and public health. The presence of some organic materials, toxic elements, radionuclides, nitrates and nitrites in drinking water can lead to cancer, other human body malfunctions and chronic illnesses.

Although the Thrace region occupies only a 3% part of Turkey, 15% of the total population of the country lives here (Fig. 1). The amount of accessible water in that region is nearly 3.4 billion m^3, which consists of 2.8 billion m^3 of surface water, 0.4 billion m^3 of groundwater and 0.2 billion m^3 other resources' water (Konukçu et al. 2004). The average amount of water that can be used per person is believed to be 300 m^3/year. The possibility of pollution in water supplies is increasing every day by the developing industry and enhancing population of the region, which has a borderline with Europe. No studies have, however, been done on the water quality with regard to its chemistry and microbial activity.

Therefore, the aim of this study was to determine microbiological and chemical quality of groundwater sources from part of Thrace in Edirne and Gelibolu (Çanakkale) area (Fig. 1) and to provide and compare the levels obtained with EU-DWD/TFC-DWD.

Geology and hydrogeology

In the study area, all the units are composed of the Cenozoic sediments (Fig. 2a). These are from base to top; Muhacir formation consisting of an alternation of marl, sandstone and calcareous sandstone (Middle Oligocene); Danismen formation comprising of sandstone, siltstone and mudstone (Middle Oligocene); Cakıl formation consisting of conglomerate, sandstone and mudstone (Middle Oligocene).

The Upper Miocene sediments, from base upwards, are; Celebi formation consisting of limestone, clay and marl; and Ergene formation consisting of an alternation of sand, pebble and clay. Pliocene sediment is Trakya formation consisting of an alternation of pebble, sand and clay; and the Quaternary deposit is alluvium.

Generally, Quaternary alluvium, Pliocene and Miocene units have great importance of viewpoint of groundwater. Alluviums, Trakya and Ergene formations can be defined as Upper aquifer (Figure 2b) and have so many (over 1000) wells in the Upper aquifer. In this region, groundwater level falls down from 190 m (Meric river in west, northwest) to 125 m (Malkara in south). Therefore, groundwater is mostly recharged and affected from the Meric and Ergene rivers. Celebi and Cakıl formations form the lower

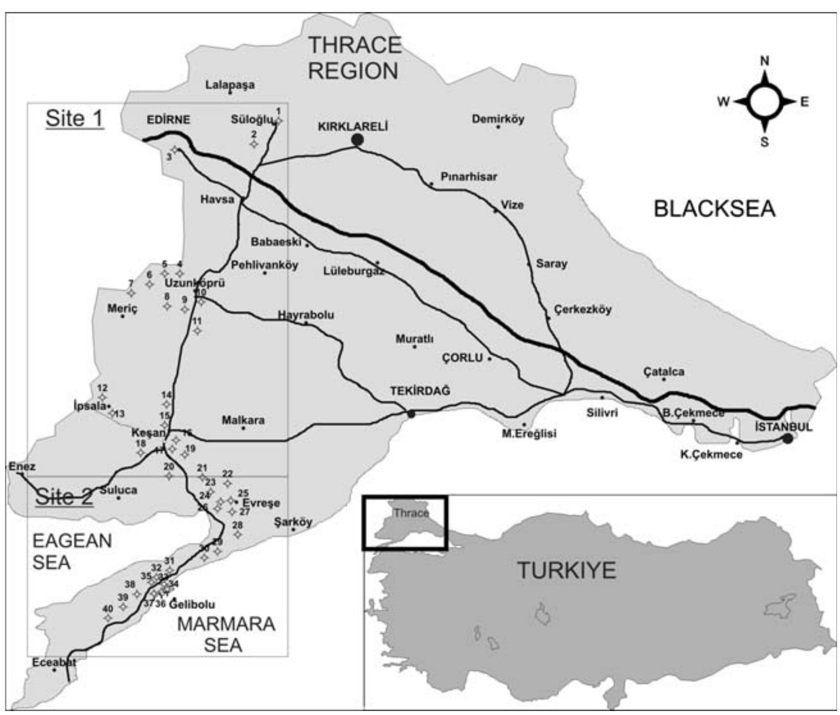

Fig. 1 Location of study areas and groundwater sampling points in West Thrace, Turkey

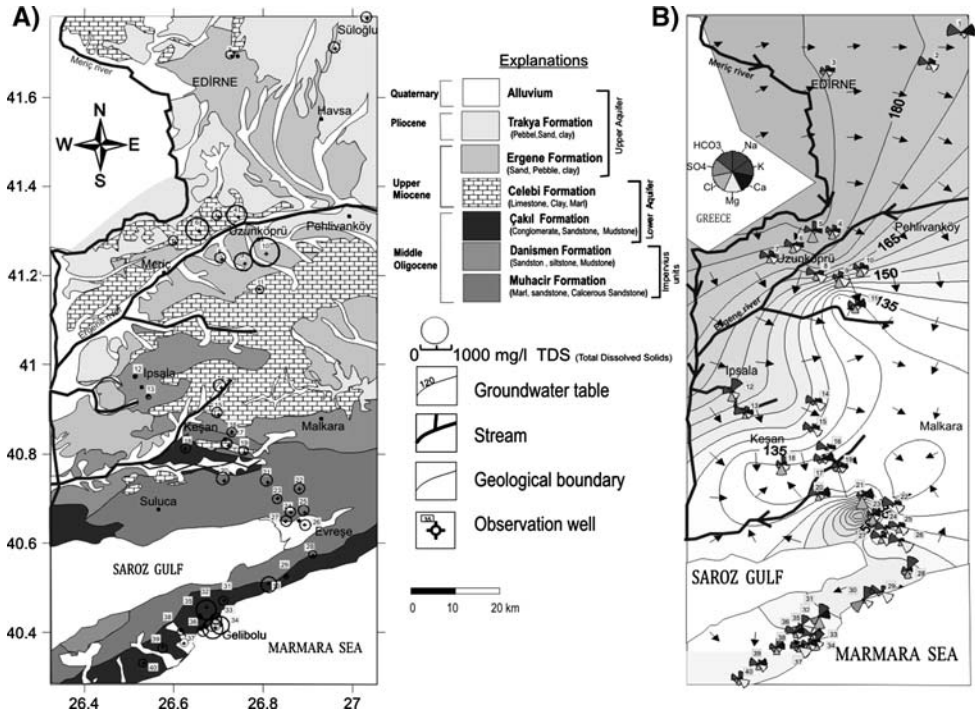

Fig. 2 **a** Hydrogeological map and TDS circle; **b** groundwater level map and pie diagram

aquifer system. In addition, Danismen and Muhacir formations are the impervious basement units.

Materials and methods

Sample collection and analysis

The total numbers of 40 groundwater samples were obtained from West Thrace region Site 1 (Edirne Area) and Site 2 (Gelibolu area, Çanakkale) (Figs. 1 and 2). All water samples were collected in sterile Schott bottles (5 l). Once collected, the samples were immediately stored on ice a dark cooler box and transported to the laboratory. The samples were stored at 4°C and analyzed within 6 h of collection. Total 23 chemical and 8 microbiological analyses were performed for each sample.

Hydrochemical analysis

Groundwater analyzed for pH, conductivity, total dissolved solids (TDS) and 21 elements (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}, Cl^{-}, SO_4^{2-}, HCO_3^{-}, NO_2^{-}, PO_4^{3-}, Cn^{-}, Al^{3+}, Fe^{2+}, Mn^{2+}, Cu^{2+}, Zn^{2+}, F^{-}, As^{3-}, Cd^{2+}, Cr^{3+} (total), Ni^{2+}, Pb^{2+}) by using the spectrophotometer. (Thermospectronic Aquamate 2000E UV visable) (Table 1). The pH and electrical conductivity (EC), were measured with a Sarto PP 50 pH, conductivity, and ion selective meter. Ammonia (NH_4^{+}) concentrations were quantified by means of the ammonia-selective electrode method as described by Standard methods (1998).

Microbiological Analysis

A total of 40 samples were examined by using the Membran Filter (MF) technique (Sartorius, 3 branch manifolds) for heterotropic plate count, total coliforms (100 ml), thermotolerant coliforms (100 ml), *E. coli*, *Enterococcus* sp., *Salmonella* sp., *Pseudomonas aeruginosa* and *Staphylococcus* sp. in 250 ml groundwater (Table 2).

Statistical analysis

To compare the some chemical characteristics of Sites 1 and 2 the groundwaters, independent samples *t* test was performed using SPSS 8.0 program package (SPSS 1997).

Results

Table 1 shows comparison of the chemical and microbiological qualities of groundwater between European Union (EU) Maximum Acceptable Directive and TFC-DWD. Table 1 also presents the summary of the chemical water quality data obtained from the groundwater.

According to the results, one sample (2.5%) assigned to Site 1 (Edirne) was acidic based (6.0) according to pH drinking water standard (EU directive, pH < 6.5). Thirty-nine (97.5%) samples had conductivity values exceeding the EU guide value of 250 µS/cm for drinking water (Table 1). Conductivity of 40 samples was determined below action levels to Turkish guide value of 2000 µS/cm

Table 1 The results of chemical analysis of groundwater supplied from two sites and comparison with EU water and Turkish drinking water directives (*n*: 40) and comparison of EU water and Turkish food codex-drinking water directives

Parameter	Site-1 Edirne The mean concentration (± SD) mg/l (*n*: 20)	Site-2 Gelibolu, Çanakkale The mean concentration (± SD) mg/l (*n*: 20)	Samples higher than permitted level (total)		Maximum acceptable concentration (MAC)	
			EU DWD (%)	TFC – DWD (%)	EU Drinking Water Directive 1998	Turkish Food Codex Drinking Water Directive 2001
pH	7.44 ± 0.12	7.17 ± 0.13	1(2.5)	0	6.5–8.5	5.5–8.5
Cond	901.40 ± 50.26	884.45 ± 61.28	39(97.5)	0	2500 μS/cm	2000 μS/cm
TDS	456.60 ± 24.31	450.65 ± 30.80		5(12.5)	Not mentioned	600 mg/ l
Cl^-	101.38 ± 12.52	75.14 ± 6.29	0	0	200 mg/ l	200 mg/ l
SO_4	129.50 ± 15.54	129.20 ± 18.24	3(7.5)	3(7.5)	250 mg/ l	250 mg/ l
Ca	116.94 ± 12.47	103.75 ± 35.81	13(32.5)	13(32.5)	250 mg/ l	250 mg/ l
Mg	60.45 ± 7.12	65.54 ± 7.74	20(50)	20(50)	100 mg/ l	100 mg/ l
K	3.22 ± 3.17	6.49 ± 4.13	3(7.5)	3(7.5)	50 mg/ l	50 mg/ l
Al	0.07 ± 0.06	0.007 ± 0.005	1(2.5)	1(2.5)	12 mg/ l	12 mg/ l
NO_3^-	52.25 ± 10.85[a]	27.45 ± 5.19[b]	11(27.5)	13(32.5)	0.2 mg/ l	0.2 mg/ l
Fe	0.08 ± 0.03	0.02 ± 0.004	1	1	50 mg/ l	45 mg/ l
Mn	0.35 ± 0.10	0.11 ± 0.06	20 (50)	20(50)	0.2 mg/ l	0.3 mg/ l
Cu	0.06 ± 0.02	0.03 ± 0.003	0	0	0.05 mg/l	0.05 mg/l
Zn	0.14 ± 0.06	0.10 ± 0.03		0	2.0 mg/ l	1.5 mg/ l
NH_4	0.0003 ± 0.00009	0.0002 ± 0.00002	0		Not mentioned	5 mg/ l
PO_4	0.61 ± 0.14[a]	0.23 ± 0.03[b]	0	0	0.50 mg/l	Not mentioned
F^-	0.24 ± 0.06	0.29 ± 0.02	0	0	Not mentioned	5 mg/l
As	0	0			1.5 mg/ l	1.5 mg/ l
Cd	0.007 ± 0.003	0.02 ± 0.004	14(35)	16(40)	0.01 mg/l	0.05 mg/l
CN^-	0.0005 ± 0.00002	0.008 ± 0.0006	0	0	0.005 mg/l	0.003 mg/l
Cr Total	0.04 ± 0.005[a]	0.02 ± 0.002[b]	5(12.5)	5(12.5)	0.05 mg/l	0.01 mg/l
Ni	0.18 ± 0.04[a]	0.08 ± 0.02[b]	31(77)	31(77.5)	0.05 mg/l	0.05 mg/l
Pb	0.09 ± 0.03[a]	0.02 ± 0.009[b]	17(42.5)	17(42.5)	0.02 mg/l	0.02 mg/l

Table 2 Compared EU drinking water directive and Turkish drinking waterstandards on the results of microbiological analysis of groundwater (*n*: 40)

Parameter	EU Standards	Turkish Standards	Positive Samples		
			(Total) (%)	**Site 1** Edirne **(%)**	**Site 2** Gelibolu-Çanakkale **(%)**
Heterotropic Plate Count (37°C)	20/ml	20/ml	(21–44/ml) (20)*	5 (12.5)	3 (7.5)
Total Coliforms	0 in 100 ml	0 in 100 ml	10 (25)	6 (15)	4(10)
Thermotolerant Coliforms	Not mentioned	0 in 100 ml	7 (17.5)	3 (7.5)	4 (10)
E. coli	0 in 250 ml	0 in 100 ml	6 (15)	3 (7.5)	3 (7.5)
Enterococcus spp.	0 in 250 ml	0 in 100 ml	19 (47.5)	13 (32.5)	6 (15)
Salmonella sp.	Not mentioned	0 in 100 ml	6 (15)	4 (10.0)	2 (5)
Staphylococcus spp.	Not mentioned	0 in 100 ml	11 (27.5)	7 (17.5)	4 (10)
P. aeruginosa	0 in 250 ml	0 in 100 ml	6 (15)	4 (10)	2 (5.0)

* Samples higher than permitted level (CFU/ml)

for drinking water. Five (12.5%) groundwater samples exceeded the TFC-DWD for TDS in drinking water. Table 2 presents the summary of the microbiological water quality data obtained for the groundwater.

Hydrochemical characteristics of groundwaters

Water samples collected from 40 wells were analyzed by physical and hydrochemical properties. Analyses were

Table 3 Total Hardness (TH) Classification

Total hardness	Concentration of $CaCO_3$ as mg/l
Soft	0–<75
Medium hard	75–<150
Hard	150–<300
Very hard	300>

accepted if their charge balance error was less than 5% (TDS up to 2 g/l) or 2% (TDS over 2 g/l). These water chemistry and quality dataset were classified using Piper and Box diagrams.

Groundwater samples in the study area are generally characterized as follows: cold (between 12 and 19 < 20°C), fresh (approximately 69–949 mg/l, TDS < 1,000 mg/l) (Fig. 2a). The conductivity values range from 106 to 1460 μS/cm, with an average value of 893 μS/cm. The relatively low conductivity groundwaters occur mainly in the Ipsala and Evrese region. These waters were found to have pH values alkaline the EU-DWD (1998) recommended value for drinking water of 6.5 to 8.5.

Groundwaters are mostly very hard and hard (approximately 124–1028 mg/l hardness as $CaCO_3$), based on Savyer and McCarty's (1967) scheme (Table 3); contain Na^+ (approximately 10–113 mg/l), Ca^{2+} (approximately 11–236 mg/l), Mg^{2+} (approximately 0–132 mg/l), SO_4^{2-} (approximately 8–100 mg/l), HCO_3^- (approximately 38–814 mg/l); and Cl^- (approximately 0–209 mg/l)(Fig. 2b). In general, the relative ion concentration level are namely; $Ca^{2+} \geq Mg^{2+} > Na^+ + K^+$ and $HCO_3^- > SO_4^{2-} \geq Cl^-$ (Fig. 3).

The sodium adsorption ratio (SAR) is in the range of 0.2–2.8(SAR < 10 mg/l), therefore, the sodium hazard is regarded as low. All groundwater are the class of C_2S_1 ad C_3S_1 type and these waters can be used on most crops and for irrigation on almost all soils based on the Wilcox (1955) classification (Fig. 4).

A Piper plot of the groundwater analysis indicates that the calcium and magnesium was the predominant cations and bicarbonate was the predominant anion in the majority of samples (Fig. 5). Waters of Ca-Mg-HCO_3 type occur in the wells of 1,2,3,4,6,10,13,17, 19,20,33,35,36 and 39. Waters of Mg–Ca–HCO_3 type occur in the wells of 7,8,9,11,14,15,16,22, 24, 25,26, 27 and 37. In addition, waters of Na–Mg–HCO_3 type occur in the wells of 12, 28 and 40, and waters of Na–Mg–SO_4 type occur in the wells of 30, 31, 32, and 34.

The groundwater on the diamond diagram shows that the nearly all groundwaters have a water type of alkali soil member are bigger than the alkali elements ($Ca^{2+} + Mg^{2+} > Na^+ + K^+$) (Fig. 5). Weak acidic roots are bigger than the strong acidic roots ($CO_3^- + HCO_3^- > Cl^- + SO_4^{2-}$) and Carbonate hardness is bigger than the 50%.

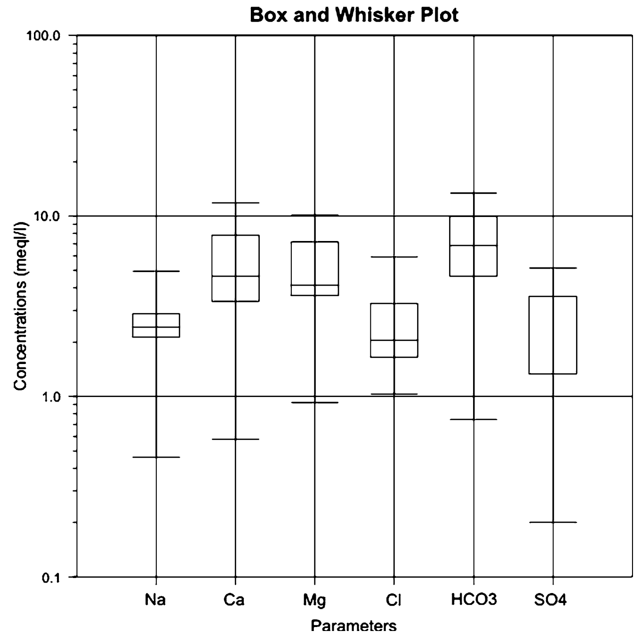

Fig. 3 Box diagram of groundwaters in West Thrace Region

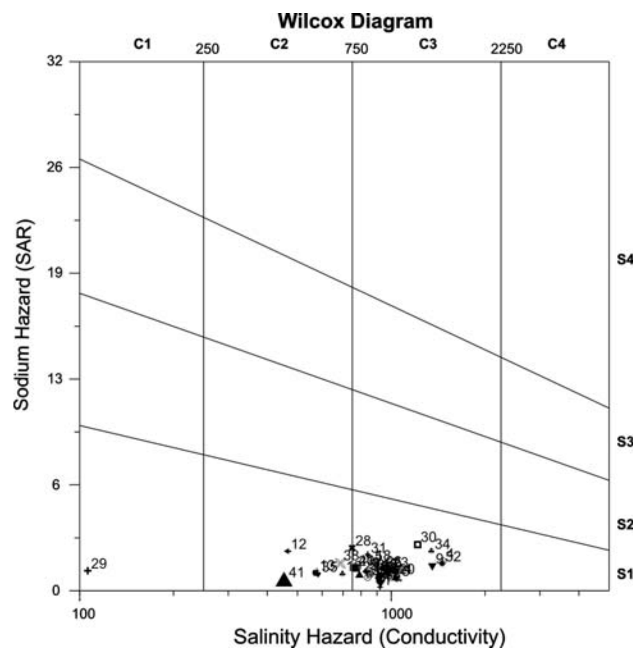

Fig. 4 Wilcox diagram of groundwaters

Evaluation of drinking water directives

Thirteen (32.5%) groundwater samples exceeded the EU and Turkish guideline value of 100 mg/l for Ca in drinking water. Twenty samples (50.0%) from groundwater had magnesium levels above the 50 mg/l. It is beneficial to have magnesium-rich drinking water, since epidemiological and clinical studies suggest that magnesium may reduce the frequency of

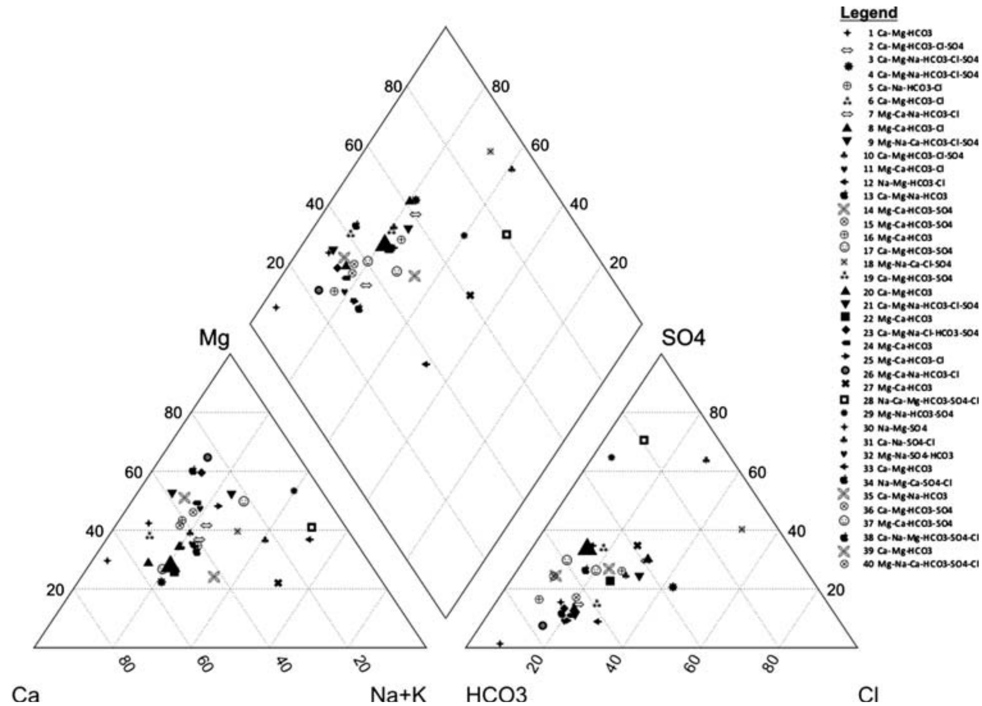

Fig. 5 Piper diagram of groundwater of West Thrace Region

sudden death in humans (Garzon and Eisenberg 1998). Three (7.5%) water samples exceeded the EU directive (250 mg/l) for sulfate in drinking water. The levels of potassium in three (7.5%) samples were above the EU and Turkish guideline value of 12 mg/l for drinking water.

One sample (2.5%) assigned to Site 1 (Edirne) exceeded for aluminum in drinking water directive of 0.2 mg/l recommended by EU and Turkish Water Directive. The maximum aluminum level recorded in this study was 1.27 mg/l (Site 1).

Eleven (27.5%) samples exceeded the EU guideline value of 50 mg/l for nitrate, but 13 (32.5%) samples violated the Turkish standard of 45 mg/l nitrate in drinking water. The differences of nitrate levels between groundwater of Sites 1 and 2 were significant ($p < 0.05$). This situation may be caused from being used of nitrate-included manures in agriculture. Excessive levels of nitrate in drinking water have caused serious illness and sometimes death. Nitrates have the potential to cause shortness of breath, blue babies syndrome in infant's diuresis, increased starchy deposits and hemorrhaging of the spleen. (USEPA 2004). One (2.5%) sample assigned to Site 1 (Edirne) exceeded the Iron (0.7 mg/l) drinking water standard of 0.2 and 0.3 mg/l recommended by EU and Turkish Directive.

Manganese concentrations in 20 (50.0%) groundwater samples exceeded the guideline value for Mn in drinking water. The maximum value reported for manganese was 50 mg/l, but the health effect of ingestion of manganese is not known. All the water samples analyzed had fluoride levels below the EU directive 1.5 mg/l recommended guideline for fluoride drinking water. The maximum fluoride level recorded in this study was 1.31 mg/l (Site 2). Hapcıoglu et al. (1997) observed groundwater and drinking water in Thrace and found out the fluorine level as 0.4867 in Edirne (Site 1). The highest level determined in that study in Edirne turns out to be 1,26 mg/l. Although no samples had a high fluoride content above the action level, the presence of fluoride in drinking water at unacceptable levels causes bone disease (pain and tenderness of the bones), and children may get mottled teeth (USEPA 2004).

The presence of toxic organic compounds at low concentrations in drinking water may create human health impairment. Fourteen (35.0%) groundwater samples exceeded the EU guideline value of 0.005 mg/l for cadmium in drinking water, but sixteen (40.0%) water samples exceeded the Turkish directive of 0.003 mg/l for cadmium. Cadmium ingestion above the drinking water action level can cause nausea, vomiting, salivation, sensory disturbances, liver injury, shock and renal failure in the short term; and the long term can cause kidney, liver, bone and blood damage as a result of a lifetime exposure at levels above the maximum contaminant level (USEPA 2004). Five (12.5%) samples assigned to Site 1 exceeded for chromium in drinking water directive of 0.05 mg/l recommended by EU and Turkish water directives. Chromium has the potential to cause damage to liver, kidney circulatory and nerve tissues skin irritation or ulceration effects from a lifetime exposure at levels above the maximum admissible concentration (USEPA 2004). Thirty-one

(77.5%) samples from groundwater had nickel levels above the 0.02 mg/l of EU directive and Turkish water guideline. People and animals that use the water in the region (Sites 1 and 2) are under the toxic risk due to nickel, a heavy metal, was found above limits in most samples in the study. Seventeen water (42.5%) samples had lead concentrations exceeding the EU and Turkish directive limit 0.01 mg/l in drinking water and the maximum lead concentrations recorded was 0.037 mg/l. Lead in drinking water above levels can delays physical or mental development infants and children; they could show slight deficits in attention span, learning abilities, and adults can have kidney problems and high blood pressure (USEPA 2004). In terms of Cr, Ni and Pb, the differences between groundwaters of Sites 1 and 2 were significant ($p < 0.05$). This case can be explained by the different industrial development levels between two different regions and the contamination of surface water with the industrial wastewater. As^{3-} was not detectable in all the groundwater and Zn^{2+}, Pb^{2+}, Cu^{2+}, NH_4^+, Cn^-, PO_4^{3-}, and Cl^- were all below their respective EU maximum acceptable concentrations or Turkish drinking water directive.

Bacteriological analyses

Krapac et al. (2002) identified more 17 bacteria genera or species in groundwater samples collected near swine lagoons. They detected the same bacteria as were detected near the pits but also identified additional *Staphylococcus* sp. and *Enterococcus* spp. in their groundwater samples. According to our results, eight (20%) samples on Site 1 and three (7.5%) samples on Site 2 exceeded the EU Water directive and Turkish Water standards guideline value in drinking water for HPC (Fig. 6a). The heterotrophic plate count is used to estimate the total amount of bacteria in water and indicates the overall microbial status of the water (Aksu and Vural 2004; USEPA 2004).

Spatially, the comparison of different well groups was engrossing. Because, increasing pattern of TDS and nitrat concentration shows similarity at the wells around Uzunköprü, Keşan and Gelibolu region (Fig. 6c,d). In addition, total coliforms, thermotolerant coliforms and *E. coli* were detected in 10 samples (25%), 7 samples (17.5%), and 6 samples (15%) of the groundwater samples at the same region wells (Fig. 6b). Total coliforms, thermotolerant coliform, *E. coli* and *Enterococcus* spp. are bacteria whose presence indicates that the water may be contaminated with human or animal wastes (ICMSF 1998). Disease-causing microbes (pathogens) in these wastes can cause diarrhea, cramps, nausea, headaches, or other symptoms. These pathogens may pose a special health risk for infants, young children, and people with severely compromised immune systems (USEPA 2004). *Enterococcus* spp. was more often detected than either thermotolerant coliforms or *E. coli*. *Enterococcus* spp. was detected in approximately 47.5% of the groundwater samples. *E. coli* was detected in 15% of the groundwater samples. Similarly, Demir et al.(2003) found out that 36,2% of samples contained *E. coli* and 42,55% of them contained *Enterococcus* spp after investigating 22 groundwater, 64 spring water, 2 ponds and 6 network water samples in Kesan region (inside Site 1). Brick et al. (2004) was also reported high *E. coli* count in Urban area of India. However, our results were quite lower than those reported. Geldreich (1996) suggested that *Enterococcus* bacteria, and are more numerous in fecal material than the other bacteria, and are more resilient in non-enteric environments which may have accounted for these bacteria being more often detected and at a larger concentration in groundwater samples than thermotolerant coliform.

Salmonella sp. was found in 15% of the analyzed groundwater samples. One possible explanation would be that water was contaminated from different resources around (septic tanks, wastewater, and livestock) and if they are used, they may probably cause various illnesses amongst both humans and animals (Aksu and Vural 2004). In a similar way, Demir et al. (2003) found *Salmonella* sp. in 11.7% of the water supplies they observed, and they stated that water in those supplies ought not to be used. According to Turkish Water Directive, there should not be any pathogen *Staphylococcus* sp. in 100 ml. of drinking water. In our study, *Staphylococcus* sp. was observed in 11 groundwater samples (27.5%), while Demir et al. (2003) cited that they found *Staphylococcus* sp. in 34% of their samples. *P. aeruginosa* was detected in 6 samples (15%) of the groundwater samples. The predominant bacteria in the field blanks were *Pseudomonas* and *Bacillus* sp. (Krapac et al. 2002). The presence of opportunistic pseudomonads in the water suggests the potential for problems in an immunocompromised population. Shallow groundwater samples commonly contained *Pseudomonas* sp., *Bacillus* sp., which occur in both soil and fecal material, and may not be indicative of livestock manure. There appeared to be no relationship between the occurrences of the relatively large concentrations of Enterococci that the samples were collected. The source of the enteric bacteria is currently unknown, but could have resulted from non-livestock animals, pit leakage, or migration of bacteria from manure application to crop fields.

Conclusions

In this study, groundwater samples collected from West Thrace region were analyzed. It was found that, in the

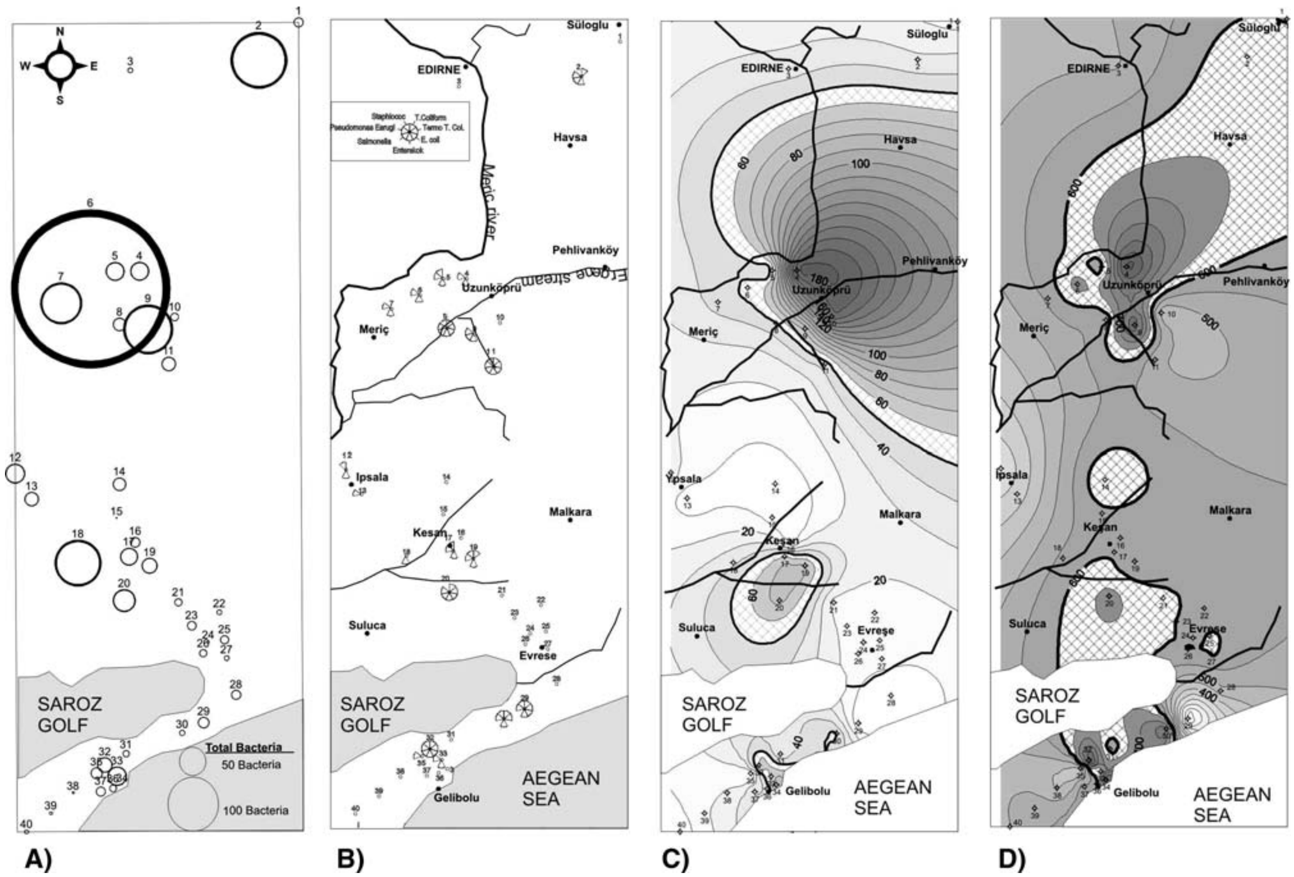

Fig. 6 Spatial variation of **a** total bacteria, **b** microbiological, **c** nitrate, and **d** TDS in West Thrace Region

region, microbiological and chemical values determined from groundwaters are mostly above the limits set by EU drinking water directive and Turkish Water Standards. The findings about the existence of indicator bacteria in high amounts in microbiological analyses demonstrate that there may be other pathogen bacteria. Especially when important pathogens like *E. coli*, *Salmonella* sp. were isolated, it is still necessary to disinfect efficiently to use the groundwater. The high number of indicator microorganism counts observed reflected the poor quality of water used by these communities. Spatially, the comparison of different well groups was engrossing. Because, the increasing pattern of TDS, nitrate concentration and microbiology shows similarity at the wells around Uzunköprü, Keşan and Gelibolu region. The people in these rural communities therefore live in constant risk of contracting water-borne and/or sanitation-related diseases as highlighted by the microbiological quality of the water they use for drinking and other domestic uses. Furthermore, heavy metals and trace elements were found after chemical analyzes in most samples. These samples may not be suitable for human consumption. Because those materials at stake have many influential effects on humans such as chronic effects and cancer.

The chemical quality and microbiological agents that adversely affect the quality of groundwater come from a variety of sources, Meric and Ergene rivers, including land application of agricultural chemicals and organics wastes, infiltration of irrigation water, septic tanks, and infiltration of effluent from sewage treatment plants, pits, lagoons and ponds used storage.

In sum, it is highly necessary to apply strong preventions immediately to save surface and groundwater supplies in the region, which rapidly develops and constitutes a location for increasing migration.

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