Vol. 12 No 4 2011

JOURNAL of

ENVIRONMENTAL PROTECTION AND ECOLOGY

Official Journal of the Balkan Environmental Association

Scientific Bulgarian Communications

Journal of Environmental Protection and Ecology is an official journal of B.EN.A. for protection of the environment and sustainable development of the region. This International Journal is edited by the **Balkan Environmental Association** (B.EN.A.) for rapid scientific and other information, covering all aspects of the problems of sustainable development and ecology.

Aims and Scope

The decision for the editing and publishing of the current journal was taken on the 1st Balkan Conference 'Education and Research within the Frame of Sustainable Development', 19–21 November, 1998, Thessaloniki, Greece, and on the 2nd Balkan Conference on Industrial Pollution, 19–21 November, 1999, Sofia, Bulgaria, of the representatives of the Balkan countries: Albania, Bulgaria, Greece, FYR Macedonia, Romania, Turkey and Serbia and Montenegro.
The Journal of Environmental Protection and Ecology is devoted to the fundamental, technological, social, political and other researches, discussions, and new ideas for protection of environment and sustainable development of the region.

The main topics of interest are: air pollution; water pollution; soil pollution; agricultural pollution; industrial pollution; risk assessment; natural and technological hazards; ecology; marine ecology; solid waste management; environmental protection and sustainable development; biochemical- and bio-protection; clean technologies; environmental radioactivity; environmental legislation; environmental management; environmental informatics; computer applications on environmental information system; environmental education and training; science and ethics-bioethics; public health-environmental medicine; wetlands-animal welfare-reserved areas protection; geoinformatics and environment; geotechnology-civil engineering impact and environment; environmental economics.

The *Journal of Environmental Protection and Ecology* is indexed and abstracted in the Science Citation Index Expanded (SciSearch®) and Journal Citation Reports/Science Edition, Thomson Scientific, and in Elsevier Bibliographic Databases (Geobase and EMBiology). The journal is refereed in Chemical Abstracts and Referativnii jurnal 'Khimiya'.
The impact factor is 0.169 for 2010.
Subject editor – N. Evtimova, proofreader – E. Tosheva.

Subscription Information
The *Journal of Environmental Protection and Ecology*, Vol. 13 (Nos 1, 2, 3, 4) will be issued on 30.03.2012, 30.06.2012, 30.09.2012 and 30.12.2012, respectively.

All subscription orders should be directed to:
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Printed by SciBulCom Ltd., www.scibulcom.net
ISSN 1311-5065

Journal of Environmental Protection and Ecology

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Vol. 12, No 4 (2011)

ISSN 1311-5065

see b.c.

Journal of Environmental Protection and Ecology 12, No 4, 1644–1655 (2011)

ASSESSMENT OF WATER QUALITY OF EAST PART OF THE ERGENE BASIN, TURKEY

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Abstract. Although Turkey, particularly the Thrace region, seems to be rich in soil and water resources in comparison to its location, population growth, pollution caused by industrialisation and possible global warming threaten the high potential cultivated lands and important water resources. Very rapid industrialisation process has been occurring in recent years in Thrace, especially in the east part, as in other regions of Turkey. This development creates many environmental problems. The region is close to the EU countries which are the most important importers of Turkey and besides it is very near to Istanbul that comprises approximately 1/7 of Turkish population. Nearness of the region accelerates development of chemicals and fertilisers used in agricultural and industrial production which have caused quick pollution of groundwater resources together with housing and industrial wastewaters. In this study 17 groundwater and 2 surface water sampling points in the Cerkezkoy–Corlu region of Thrace were chosen. Water samples were collected during a 12-month period. All samples were analysed for Cu, Fe, Zn, Mn, Cr, Cd, Pb, Ca^{2+}, Mg^{2+}, K^{+}, HCO_3^-, SO_4, Cl, and NO_3 ions. Analyses show that Cu, Cr and Pb contents in some samples exceed TSE, WHO and EPA standards.

Keywords: the Ergene basin, water quality, pollution.

AIMS AND BACKGROUND

Although Turkey, particularly the Thrace region, seems to be rich in soil and water resources in comparison to its location, population growth, pollution caused by industrialisation and possible global warming threaten the high potential cultivated lands and important water resources[1].

Very rapid industrialisation process has been occurring in recent years in Thrace, especially in the east part, as in other regions of Turkey. This development creates many environmental problems. Procurement of raw material, water, energy and qualified labour, which are required by the industry, is easier than in the other regions. The region is close to the EU countries which are the most important importers of Turkey and besides it is very near to Istanbul that comprises approximately 1/7 of the Turkish population. Nearness of the region accelerates development of industry[2]. Rapid growing industry in the region brings with itself some environmental problems. In the region, there are 992 industrial operations with different sizes, particularly within textile and food sector. The economy of the region has been dependent on industrial and service sectors instead of agriculture.

Chemicals and fertilisers used in agricultural and industrial production have caused quick pollution of ground water resources together with housing and industrial waste waters. For example, 40 000 da of rice and sunflower and other plants which are irrigated from the Ergene river, one of the most important rivers in the region, are facing with crop losses up to 50% due to water pollution[3].

Crop losses caused by pollution are estimated according to the studies in the region in 1996 and 1997; and are proportioned to total yield which will be obtained under normal conditions, so yield losses of agricultural producers have been determined as 43% in rice, 33% in sunflower and 30% in wheat[4].

Intensive agriculture took place in the study area and more than 500 deep wells for irrigation result in declination of the water levels[5].

Water is very vital for nature and can be a limiting resource to men and other living beings. Water quality is influenced by natural and anthropogenic effects including local climate, geology, etc., and construction of dams and embankments, irrigation practices[6]. Understanding the sources, their interaction, and effects of water pollutants is essential for controlling pollutants[7]. One of the most significant contaminants in the waters are heavy metals such as copper, zinc, lead and chromium[8–12]. Copper is known as not being a cumulative systemic poison, however, large doses (>100 mg) of copper are harmful to humans and might cause central nervous system disorder and adverse effects on Fe-metabolism that results in liver damage. Excess copper may also be deposited in the eyes, brain, skin, pancreas and myocardium[13]. Lead is a cumulative poison to humans and its major effects are impairment of hemoglobin and porphyrins synthesis. Zinc causes muscular weaknesses and pain, irritability and nausea[14]. Chromium which is discharged from steel and pulp mills, erosion of natural deposits, causes allergic dermatitis. The use of fertilisers and pesticides in agricultural operations leaching from septic tanks, sewage, erosion of natural deposits can cause nitrate pollution. Infants below the age of six months who drink water containing nitrate in excess of the MCL could become seriously ill and, if untreated, might die. Symptoms include shortness of breath and blue-baby syndrome[15].

In the last century, the impact of changing land use patterns has caused stress on all types of water bodies including those under the ground. Surface water quality monitoring is very important to support terrestrial ecosystem[16]. Water quality pertaining to shallow coastal aquifers has recently been studied worldwide for different purposes.

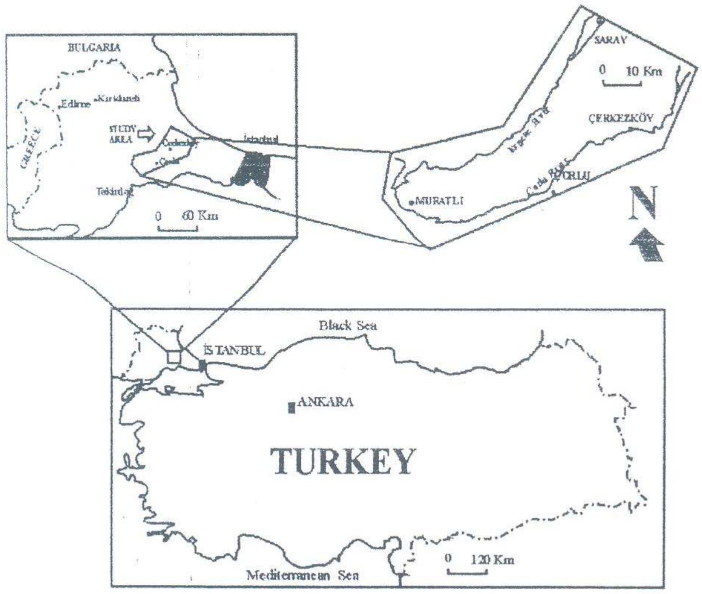

Fig. 1. Location map of the study area

The Thrace region is important for agriculture and industry of Turkey (Fig. 1). The water systems and qualities must be determined and monitored. According to these objectives:

- the origin of the aquifer waters and their relations with contamination sources in the aquifer are discussed;
- preliminary investigations for water pollution level in the study area are being carried out.

STUDY AREA

Study area is situated in the north-west of Turkey, which is named as the Thrace region. While northern part of the study area is mountainous, the other part is a plain covered with hills with low slopes. Drainage area of the eastern parts of the Ergene and Corlu rivers constitutes the study area. Organised industrial zones of Corlu and Cerkezkoy and European Free Zone (EFZ) are also located in the study area. Beside these, sunflower and wheat production is the main livelihood for the inhabitants.

GEOLOGY AND HYDROGEOLOGY

The general geology of the study area is presented in Fig. 2. Geological structures around the area consist of three main rock groups. Metagranites, schistic gneissic granites which outcrop at the north of the area, constitute the basement rocks of the study area. These are overlain unconformably by tertiary aged sedimentary rocks, marine limestone, gravel stones, sand stones, clay stones, and silt stones. These rocks outcrop in a large area. Quaternary basaltic volcanic rocks overlie unconformably the sedimentary rocks. Alluvium constitutes the youngest unit and covers a large extension in the study area (Fig. 2).

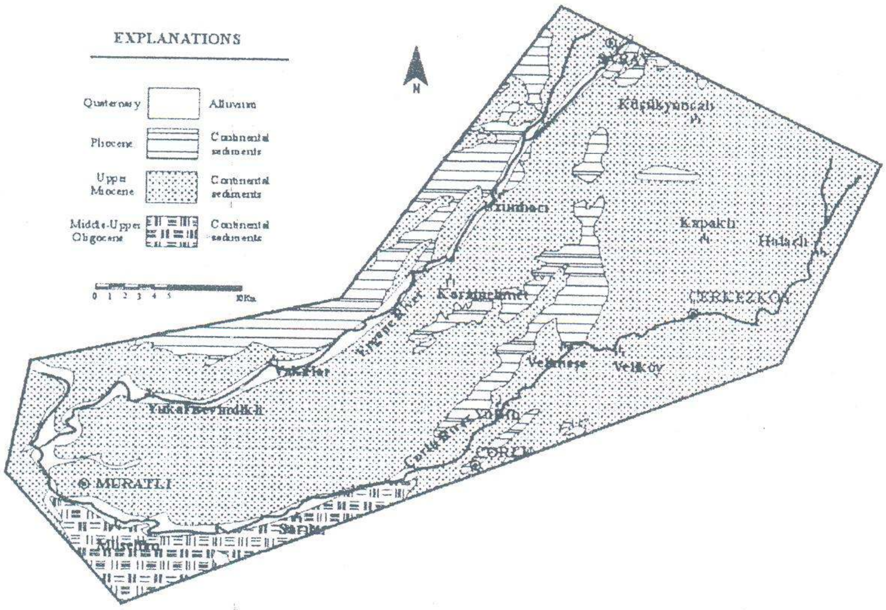

Fig. 2. Geological map of the study area

The study area consists of two different physiographical units, which are: flood plain soils (young and old river terraces), and delta soils. Study area is mainly flat and slightly sloped. 30% of the land in the study area are used as arable field. Top soil texture varies from heavy to very heavy soil. Soil colour ranges from brown to dark brown and shows high plasticity, water absorption and swelling properties. Main agricultural production in the study area is sunflower, wheat, and corn. Stockbreeding is also being observed[17].

There are three organised industrial zones (OIZ) in the region. While production in the Cerkezkoy OIZ is mainly for electronic and textile products, the production in the EFZ is for textile, and it is for leader in the Corlu OIZ.

Terrestrial climate dominates in the study area. Annual precipitation average is about 509 mm; the maximum is 180.3 mm, the minimum is 72.2 mm. Monthly temperature average is 12.1°C. Annual potential evaporation is 791.3 mm according to the Penmann budget[5].

The most important fresh water resources are the Ergene river and the Creek Corlu in the region. Both of these streams emerge from the Yildiz mountains. Total drainage area is about 1000 km^2 till to the flow observation station near the village Inanli. The other water resources in the region are wells. There are more than 500 wells in the region which are used for irrigation and drinking. The depth of these wells ranges from 100 to 150 m. There are no lakes or other natural water resources in the region.

15% of the study area are flat, whereas 75% of the area have an undulated topography. The soil depth ranges between 2–3 m. This area consists of the sediments of the river Ergene and the Creek Corlu.

EXPERIMENTAL

Sampling. The survey was conducted from May 2003 to April 2004 in two surface sampling points and 17 groundwater sampling points (Fig. 3). All water samples were collected every month during the study. Coordinates of the sampling points were determined by global positioning system (GPS).

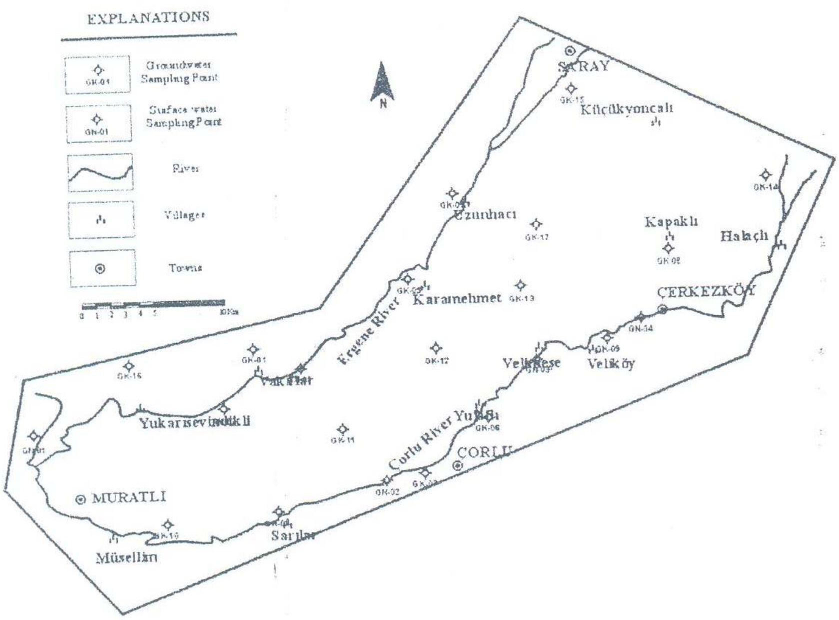

Fig. 3. Location map of the sample collection wells

Groundwater samples were collected from wells and rivers of Ergene and Corlu. All the collected water samples were stored in a cooler on ice in the field and brought to laboratory. Samples can not be analysed in the field or at the lab. They were immediately transferred to a refrigerator and stored at 4°C. The samples were preserved according to specific test requirements and immediately analysed for Cu, Fe, Zn, Mn, Cr, Cd, Pb, Ca^{2+}, Mg^{2+}, K^{+}, HCO_3^-, SO_4^{-2}, Cl^- and NO_3 ions according to Ref. 18 (Table 1). All water samples were filtered through Whatman filter papers before analyses. The pH of the water samples for heavy metal analysis was adjusted to pH 2 by concentrated nitric acid. Concentrations of Cu, Fe, Zn, Mn, Cr, Cd and Pb were determined by inductively coupled plasma-atomic emission spectroscopy (ICP-AE). Calibration was made according to standards and calibration curve was established.

Table 1. Average value of major elements in water resources

Water type	Sample number	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^-N (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	SAR*
Ground-water	GK01	423	80.5	22.3	8.8	122.3	27.8	67.2	0.6	7.76
	GK02	402	12.2	16.4	0.5	47.5	7.6	5.8	0.9	1.11
	GK03	696	29.4	44.2	1.9	74.6	15.5	32.4	0.9	4.83
	GK04	440	8.9	2.5	3.2	66.0	8.8	19.2	4.8	3.14
	GK05	378	19.0	8.3	4.4	65.4	12.6	8.9	1.0	1.43
	GK06	375	17.3	6.2	1.9	50.1	6.4	10.0	0.5	1.87
	GK07	638	40.8	96.3	110.3	134.4	15.3	46.3	1.5	5.36
	GK08	529	37.6	15.3	4.0	131.5	19.2	42.2	1.1	4.87
	GK09	491	24.4	10.8	1.4	75.8	15.8	22.6	0.6	3.34
	GK10	696	28.8	44.2	1.9	74.6	15.5	32.4	0.9	4.83
	GK11	635	41.0	96.0	110.3	134.2	11.3	45.3	1.2	5.31
	GK12	373	17.0	6.1	2.0	48.0	6.1	9.2	0.2	1.77
	GK13	489	24.4	10.7	1.6	75.5	15.9	22.8	0.6	3.37
	GK14	520	37.4	15.2	3.5	131.4	18.2	41.2	1.0	4.76
	GK15	445	7.9	2.2	3.0	66.8	9.2	19.4	4.6	3.15
	GK16	404	11.8	16.2	1.2	47.2	7.0	5.0	1.2	0.96
	GK17	375	19.0	8.0	4.0	65.0	12.4	8.2	0.9	1.32
Surface water	GN01	*	1984	395	*	78.0	20.7	1598.5	36.7	227.55
	GN02	*	1417.6	425	*	58.0	18.2	1278.5	10.9	207.13

*Average sodium absorption rates.

The pH and electrical conductivity (EC) of the samples were measured at sampling site using WTW-multi parameter instrument.

RESULTS AND DISCUSSION

QUALITY OF CHEMICAL DATA

In order to ascertain the quality of the chemical data before manipulation, ionic balance error is being checked, which is explained as follows[19,20]:

$$\text{reaction error} = \frac{\Sigma \text{ cations} - \Sigma \text{ anions}}{\Sigma \text{ (cations} - \text{anions)}} \times 100$$

where Σ cations is the sum of concentrations of cations (meq l^{-1}) and Σ anions – the sum of concentrations of anions (meq l^{-1}).

If the reaction error of chemical data set is greater than 10%, the quality of the analysis is questionable. In this study, reaction errors are given in Fig. 4. All the reaction errors are within the 10% range. Therefore, the quality of the chemical data is acceptable according to ionic balance criteria.

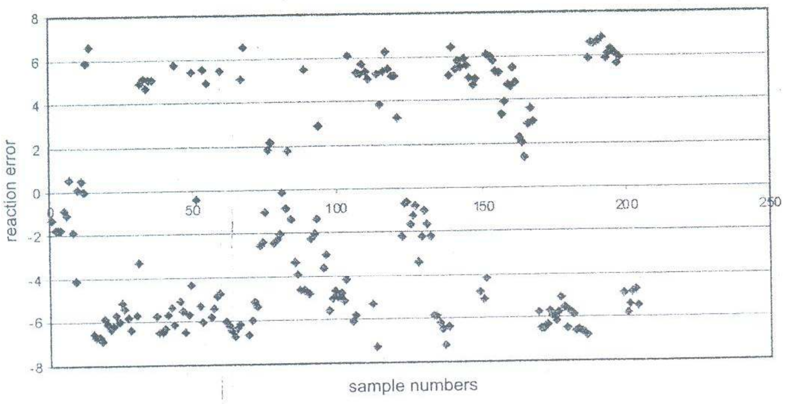

Fig. 4. Ionic balance reaction error

ANIONS AND CATIONS

Average values of major anions and cations measured during the 12-month period are presented in Table 2. The results were plotted on the Schoeller and Piper diagrams (Figs 5 and 6). According to the Piper diagram, all the samples except surface waters are rich in Na and HCO_3. The Schoeller diagram (Fig. 5) shows that samples 1, 7, 8, 11 and 14 are rich in Ca, Mg, Na and HCO_3, and samples 5 and 12 are rich in Ca, Mg and HCO_3

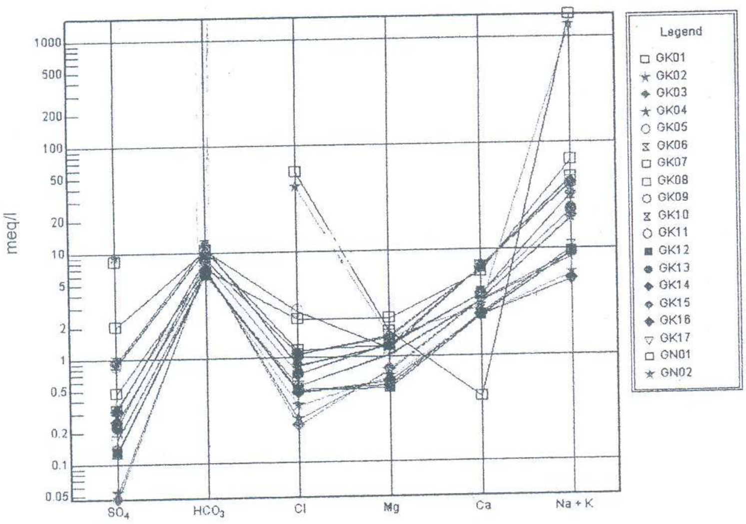

Fig. 5. Chemical analysis of water of the study area plotted on the Schoeller diagram

Table 1. Average value of major elements in water resources

Water type	Sample number	HCO_3^- (mg/l)	Cl^- (mg/l)	SO_4^{2-} (mg/l)	NO_3^-N (mg/l)	Ca^{2+} (mg/l)	Mg^{2+} (mg/l)	Na^+ (mg/l)	K^+ (mg/l)	SAR*
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	GK16	404	11.8	16.2	1.2	47.2	7.0	5.0	1.2	0.96
	GK17	375	19.0	8.0	4.0	65.0	12.4	8.2	0.9	1.32
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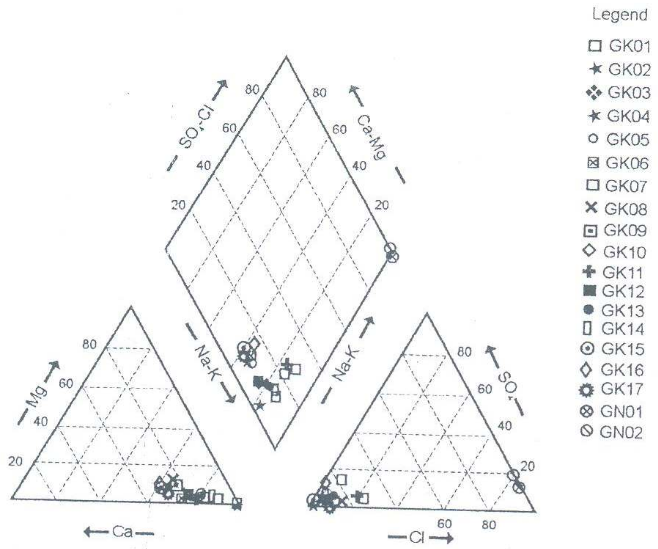

Fig. 6. Chemical analysis of water of the study area plotted on the Piper diagram

Table 2. Average value of minor element in water resources

Water type	Sample number	Cu (mg/l)	Fe (mg/l)	Zn (mg/l)	Mn (mg/l)	Cr (mg/l)	Cd (mg/l)	Pb (mg/l)
Ground-water	GK01	0	0.040083	0.00125	0	0	0.002583	0.305917
	GK02	0	0.2605	0	0.027667	0.022417	0.003833	0.086167
	GK03	0	0.118667	0	0.02075	0.09425	0.015583	0.163083
	GK04	0	0.068333	0	0.0095	0	0	0
	GK05	0	0.112727	0	0	0	0	0
	GK06	0	0	0	0.011167	0.156417	0.01225	0.26475
	GK07	0	0.182833	0.69875	0.00325	0.137	0.01425	0.14675
	GK08	0	0.031333	0.037083	0	0	0	0.436083
	GK09	0	0.137333	0	0	0	0	0
	GK10	0	0.129455	0	0.022667	0.09425	0.015583	0.163083
	GK11	0.0	0.281333	0.69875	0.00325	0.137	0.01425	0.14675
	GK12	0.0	0	0	0.012182	0.156417	0.01225	0.26475
	GK13	0	0.137333	0	0	0	0	0
	GK14	0	0.031333	0.037083	0	0	0	0.436083
	GK15	0	0.068333	0	0.0095	0	0	0
	GK16	0	0.2605	0	0.027667	0.022417	0.003833	0.086167
	GK17	0	0.146667	0	0	0	0	0
Surface water	GN01	1.34	1.86	0.242		0	0	0.211
	GN02	1.52	2.27	0.271		0	0.248	0.222

Groundwater can be rich with any ion depending on the chemical composition of rocks. The cation exchange order in the Schoeller diagram, which is Ca> Mg> Na + K, represents waters from litology of dolomites, marns, sandstones and clays. The aquifer in the study area is composed of sedimentary rocks of the Ergene basin. The lithology changes within rocks, change of ions can particularly affect the properties of groundwater[21]. Clayey parts of the aquifer absorb Cl ions and reduce the concentration in the groundwater. High Ca ion concentration results from the limestone which is among the clastic forming the alluvium aquifer located in the north of the region. The high Cl concentration in the surface waters shows that these waters are polluted externally. Especially, this is caused by the fact that the factories in the region direct their waste waters to the Creek Corlu. The high nitrate concentration in the 7th and 11th wells again shows that these wells were polluted. According to the EPA standards, nitrate concentration value should be 10 mg/l in potable water, and according to TS 266 and WHO, it should not be over 50 mg/l. High nitrate values may cause fatal illnesses especially for babies[14]. The reason of the pollution in the region is thought to result from the agricultural activity and the use of fertilisers.

The pH values in the wells range from 6.8 to 7.1 and those in the surface waters – from 7 to 7.1. The electrical conductivity (EC) is a valuable indicator of mineral dissolved in water. The EC values range from 1051 to 381 μΩ. The recommended value of EC for potable water is 2500 μΩ (Ref. 22).

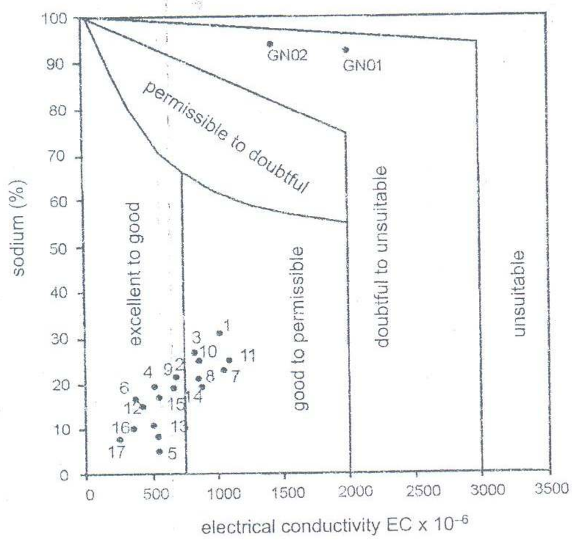

Fig. 7. The Wilcox diagram for irrigation classification of the water

According to the Wilcox diagram, waters of wells 2, 4, 5, 6, 9, 12, 13, 14, 15 and 16 are classified as 'excellent to good', samples of wells 1, 3, 7, 8, 10 and 11 are classified as 'good to permissible'. Surface waters with very high Na values are not suitable for irrigation.

Average sodium absorption ratios (SAR) are between 0.96 and 5.36 (Table 1) in the area. SAR values of surface waters are higher than those of groundwater.

The hardness of water can naturally range from zero to hundreds of milligrams per liters (or parts per million). Waters with a total hardness of 100 to 500 mg/l are in the limits[22]. In this study, water samples are between 144.98 to 419.86 mg/l.

TRACE ELEMENTS AND HEAVY METALS

Cu, Fe, Zn, Mn, Cr, Cd, and Pb analysis of water samples are done and compared with standard values for potable water suggested by US EPA (Ref. 14), WHO(1970) and TSE (Ref. 23) (Table 2) Cu values of surface waters exceed US EPA and WHO limits ranging from 1.34 to 1.52 mg/l, Fe values of wells 2, 3, 5, 7, 9, 10, 11, 13, 16 and 17 exceed WHO limits. While wells 2, 11 and 16 also exceed TSE limits, surface samples GN01, GN02 exceed all US EPA, WHO, TSE standard values.

Total cromium values of wells 6, 7, 11 and 12 also exceed US EPA, WHO,TSE limit values, while wells 3, 10 and 16 exceed only WHO and TSE limits. Cd values of wells 3, 6, 7, 10, 11 and 12 and surface water sample No GN02 exceed all the limits of the standards mentioned, ranging from 0.12 to 0.015 mg/l.

Pb values of wells 1, 3, 6, 7, 8, 10, 11, 12 and 16 and surface waters GN01 and GN02 are above the limits. Especially, wells 8 and 14 had an average value of 0.43 mg/l which is 28 times greater than those permitted by EPA for potable water. Possible reasons for Pb and Cr contamination are the textile industry and untreated wastewaters of fibre dying directed to the Creek Corlu. Effluent discharge from textile and dyestuff industries to neighbourhood water bodies and wastewater treatment systems cause significant health concerns.

CONCLUSIONS

Waters sampled from aquifers of east part of the Ergene basin generally showed different properties.

- According to the Schoeller diagram, surface waters were rich in Na^+ and Cl^-, and this situation seems to reveal that these waters are contaminated from outside agents. One of the possible reasons for this contamination is that wastewaters of textile factories are directed to the Creek Corlu.
- The high nitrate concentration in the 7th and 11th wells shows that those wells were contaminated. According to the EPA standards, nitrate concentration value should be 10 mg/l in potable water, and according to TS 266 and WHO, it should not be over 50 mg/l. High nitrate values may cause fatal illnesses especially for babies (EPA). The reason of the pollution in the region is thought to result from the agricultural activity and the misuse of fertilisers.
- Cu values ranging from 1.34 to 1.52 mg/l of surface waters exceed US EPA and WHO limits, Fe values of wells 2, 3, 5, 7, 9, 10, 11, 13, 16 and 17 exceed WHO limits, while wells 2, 11 and 16 also exceed TSE limits, surface samples GN01, GN02 exceed all US EPA, WHO,TSE standard values.

• Total chromium values of wells 6, 7, 11 and 12 also exceed US EPA, WHO, TSE limit values, while wells 3, 10 and 16 exceed only WHO and TSE limits, Cd values of wells 3, 6, 7, 10, 11 and 12 and surface water sample No GN02 exceed all the limits of the standards mentioned, ranging from 0.12 to 0.015 mg/l.

• Pb values of wells 1, 3, 6, 7, 8, 10, 11, 12 and 16 and surface waters GN01 and GN02 are above the limits. Especially wells 14 and 8 had an average value of 0.43 mg/l which is 28 times greater than those permitted by EPA for potable water. Possible reasons for Pb and Cr contamination are untreated wastewaters of fibre dying industry directed to the Corlu river.

• Up to now, we have not had important environmental problems in the study area, but some of the water analyses show some heavy metals such as Cr, Pb, Cd, Cu and Fe. Also according to the Wilcox diagram surface waters are not suitable for irrigation due to high Na concentrations. This may negatively affect the quality of the agricultural products which are irrigated with those waters. Moreover, the use of those waters for drinking may cause several different health problems for the people in the region. Therefore, more cautions must be taken into consideration for agriculture and habitats in the study area.

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Received 6 July 2009
Revised 10 September 2009