

Assessment of groundwater pollution around Torbali, Izmir, Turkey

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Abstract Torbali region is located near Izmir, Turkey. Industrial activities in this region have been developing from last two decades. The untreated industrial effluents discharged into the Fetrek River causes groundwater pollution in the region. Since groundwater resources of the region are used for drinking, agricultural and industrial purposes the groundwater quality assessment is done by analyzing the concentrations of main cations (Na^+ , K^+ , Ca^{2+} , Mg^{2+}) and anions (Cl^- , SO_4^{2-} , NO_3^- , HCO_3^-). Additionally, physical and chemical parameters (EC, total hardness, Eh, O_2 and pH) were determined. The results show that the concentrations are generally within drinking-water limits. Only the results of TDS and EC concentrations exceed the permissible limits for drinking water in the industrial belt of the region, while NO_3^- values exceed the permissible limits in the vicinity of the agricultural area. Concentrations are expected to increase in the next years as no effective sewage collection and treatment is in place.

Keywords Groundwater · Torbali · Contamination · Turkey

Introduction

The adverse effects of agricultural and industrial activities and urban development on adjacent groundwater have prompted investigations on the quality of these sources. Singh et al. (2006) investigated the groundwater quality in the Gangetic alluvium plain, India, and observed high chloride, phosphate, nitrate and sulphate concentrations where intensive agricultural and industrial activities exist and classified the groundwater as moderately hard, normal sulphate and chloride type in the region. Melian et al. (1999) examined groundwater quality for Balatina and Carpineni areas where agricultural land use are high to improve rural drinking water conditions in Republic of Moldova and as a result poor-quality drinking waters were observed around the villages and the contaminants values at agricultural areas were observed rarely higher than the undeveloped areas. Another study was done by Ahn and Chon (1999) who investigated groundwater contamination for Asan agricultural zone and Gurogu industrial and residential area in Korea, and high contents of NO_3^- , Cl^- , SO_4^{2-} , HCO_3^- , Na^+ , Ca^{2+} , Mg^{2+} and K^+ ions were observed in groundwater from the Gurogu area, in comparison with those from the Asan area and NO_3^- was indicated as the principal pollutant for the both areas and the major source of NO_3^- pollution were considered as sewage waste in Gurogu Area and Cl^- concentration over the critical level was observed in shallow groundwater site in the industrial area. In Asan area, shallow groundwater around stock farms was contaminated with nitrates, but around the factories nitrate pollution was observed both shallow and deep groundwater, and Cl^- concentrations in the influential area of factories and stock

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farm were higher than beyond the influential area. Elhatip et al. (2003) examined the groundwater quality of Incesu-Dokuzpinar springs in Turkey and they observed high concentrations of NO_3^- , Na^+ and Cl^- around the springs and indicated that the reason of this contamination was untreated sewage and agricultural wastes in the area. According to a study by Umar and Ahmad (2000) in Ganga basin, India, the concentrations of heavy metals Fe, Mn, Cd, Pb and Cr^{+6} were higher than the permissible limits and the sources of the heavy metal pollution were determined as household refuses, sewage and industrial effluents.

In this study Torbali region near Izmir, Turkey is selected as the study area with industrial activities having started nearly 20 years ago and still expanding in the region. Among others, cigarettes, automotives, oil and textile are produced in the area. Before the industrial activities, agriculture was the dominant sector in the region and the importance of the region has increased with the starting of the industrial activities.

Torbali region is located between $38^\circ114'$ – $38^\circ225'$ north latitude and $27^\circ336'$ – $27^\circ413'$ east longitude and the studied area is approximately 83.4 km^2 . The region is located on the western part of Turkey, approximately 45 km south of Izmir City (Fig. 1).

The industry and solid waste landfill areas are located near the Fetrek Stream and to the north of Torbali City as shown in Fig. 2. The landfills are situated above the high permeability materials and due to lack of the collecting and treating system, leachate percolates from soil to groundwater. There is not an appropriate sewage collection system in the region.

Growth of the industrial activities during the last two decades causes increase of the population of the region. According to general census schedules

obtained from Turkish Statistical Institute, the population of Torbali was about 72,000 in 1990; this value has increased to more than 93,000 in 2000. Average annual population growth rate in the region is 26%, at the center of the city this rate is calculated as 59%. Considering the population growth rates, water demand must also increase.

Kirer (2002) showed that groundwater quality in the region exceeded the permissible limits for nitrate, calcium, nitrite concentrations which were regulated by Environmental Protection Agency and Turkish Standards for drinking water. According to Simsek (2002), the concentrations of the parameters in the leachate were observed $4,900 \mu\text{S}/\text{cm}$ and 18,800 ppm for Electrical Conductivity (EC) and Total Dissolved Solids (TDS), respectively.

The aim of this study is to investigate the effects of the industrial activities and increase of human population on groundwater quality in the region since groundwater resources are widely used for drinking, agricultural, and industrial purposes.

Geology and hydrogeology

In the region the most important aquifer which benefits from the groundwater is Cenozoic alluvial which is composed of gravel, sand, marble and schist. The Cenozoic clay and Mesozoic schist form the impervious layer beneath the alluvial aquifer. According to drilling wells (METU 2000), three alluvial aquifers were determined in the region. Clay forms impermeable layers between these aquifers with some geological windows within the impermeable layers (Fig. 3). Thickness of the alluvial aquifer reaches approximately 80 m in the middle of the region.

Fig. 1 The location of the studied area



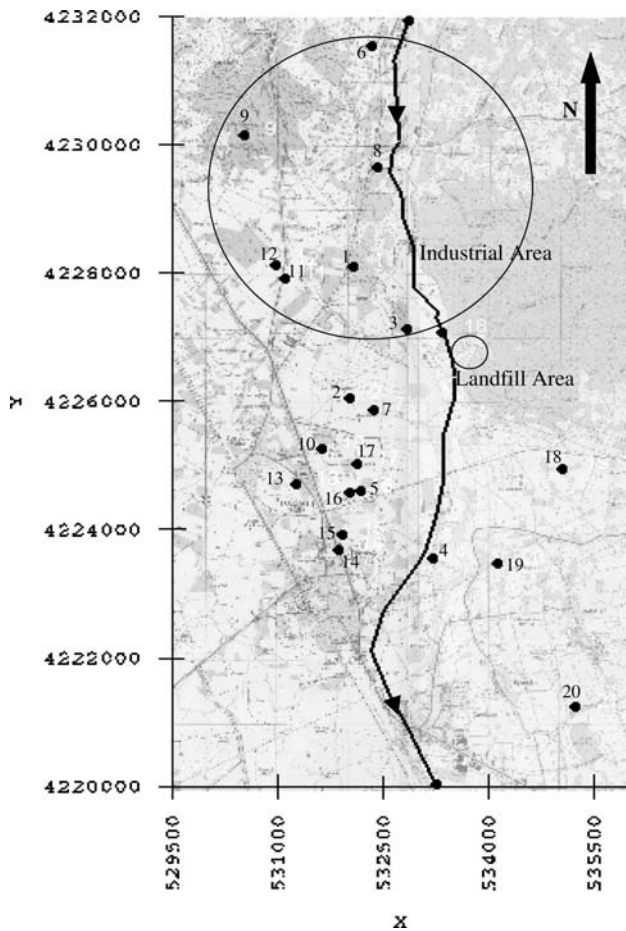
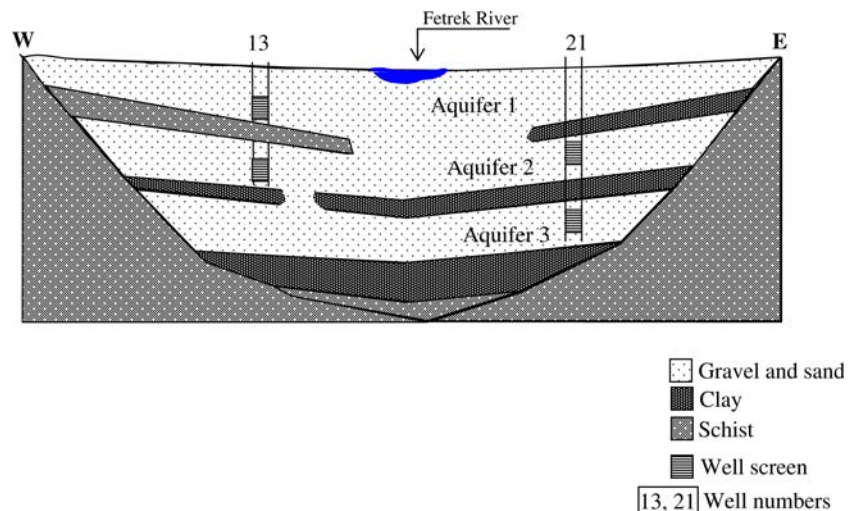


Fig. 2 The map of the study area and location of the samples

Simsek (2002) reported a hydraulic conductivity of the alluvial aquifer is around 10^{-4} m/s while it is around 10^{-3} m/s along the Fetrek River. Groundwater is artificially recharged with water from Fetrek River in infiltration ponds which are constructed by the State Hydraulics Works (DSI). The infiltration rate from the

Fig. 3 Schematic illustration of aquifer system of study area



river into the aquifer is estimated approximately 28.5×10^6 m³/year (Simsek 2002).

According to the precipitation data from the station 6296 which belongs to Turkish State Meteorological Service the average amount of annual rainfall is approximately 680 mm and the average annual temperature is 17°C.

Sample collection

Twenty samples were collected for assessment of groundwater quality during March 2006 from the wells which are represented in Fig. 2.

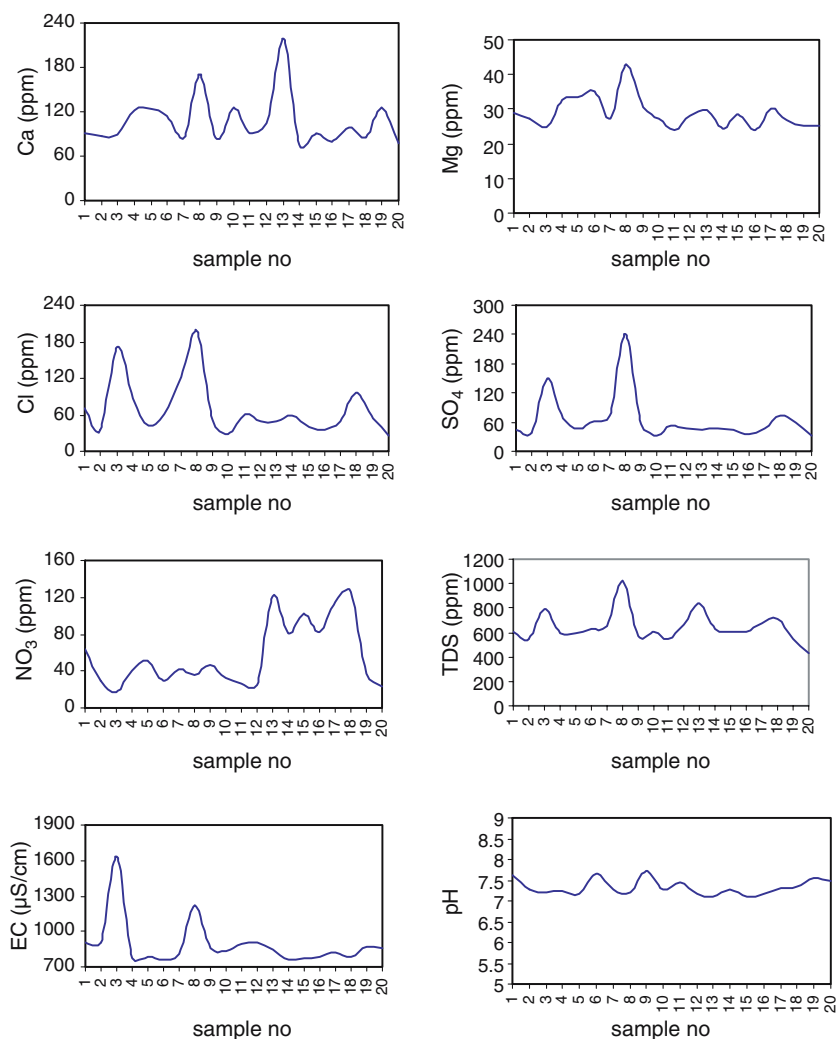
AAS Analytik Jena NovAA 400G (atom absorptions spectroscopy) and ICP-AES Trace Scan (Thermo Jarrell) were used to analyze Na⁺, K⁺, Fe²⁺, Mn⁺ and Ca²⁺, Mg²⁺, respectively. The anions (Cl⁻, SO₄⁻, NO₃⁻) were analyzed using Dionex DX-120 Ion chromatograph. The ion chromatographic system consists of IonPac AG22 (4 × 50 mm) guard column, IonPac AS22 (4 × 250 mm) separator (analytic) column, anion self-regenerating suppressor (ASRS-ULTRA II 4 mm) and a DS4 detection stabilizer. The output signals (μS) of anions are observed according to retention times. Calibration process is done with seven standards and concentrations are obtained at ppm level by using the calibration curves. In atom absorption spectroscopy first the sample is atomized then light of a specific frequency is passed through the vapor to determine the amount of absorption. Concentrations are determined through the calibration curves after calibrating the instrument with standards of known concentration.

EC, pH, O₂, HCO₃⁻, redox and total hardness (TH) were analyzed in the field as soon as water samples are

Table 1 Maximum, minimum and mean values of the parameters

Parameter	Minimum	Maximum	Mean
Na ⁺ (ppm)	12.10	140.20	36.50
Ca ²⁺ (ppm)	67.84	219.50	105.32
Mg ²⁺ (ppm)	23.90	42.96	28.62
K ⁺ (ppm)	1.21	7.81	2.39
Fe ²⁺ (ppm)	0.00	0.13	0.03
Mn ²⁺ (ppm)	0.00	0.04	0.01
Cl ⁻ (ppm)	25.13	197.36	67.97
SO ₄ ²⁻ (ppm)	31.91	241.65	65.15
NO ₃ ⁻ (ppm)	5.54	125.94	53.97
HCO ₃ ⁻ (ppm)	221.96	402.75	310.44
TDS (ppm)	433.54	1019.63	633.85
TH (°F)	29.3	60.7	39.8
EC (μS/cm)	760	1631	916
pH	7.09	8.73	7.4
Eh (mV)	278	528.25	385.8
O ₂ (ppm)	4.45	9.95	7.8

collected by using field kits WTW Cond 340i/SET, WTW pH 340i/SET, WTW Oxi 340i/SET, Carbonate and Total Hardness kits.

Fig. 4 Graphs of the parameters

Total dissolved solids (TDS) were calculated by summing the cations and anions ions in the water.

Results

The maximum, minimum and mean values of the parameters are presented in Table 1. Figure 4 represents the graphs of some parameters which are measured and computed.

Na⁺ concentrations vary between 12.1 and 140 ppm which are lower than permissible limits which were regulated by World Health Organization (WHO 1998). The equal concentration map of Na⁺ is shown in Fig. 5a.

Although the region is not located near the sea, Cl⁻ concentrations are observed between 25.1 and 197 ppm. Lack of the sewage system in the region and wastewater discharge from industry into the Fetrek River may be the reasons for observing Cl⁻ concentrations in the

region. The contour map of equal concentrations values for Cl^- is given in Fig. 5b.

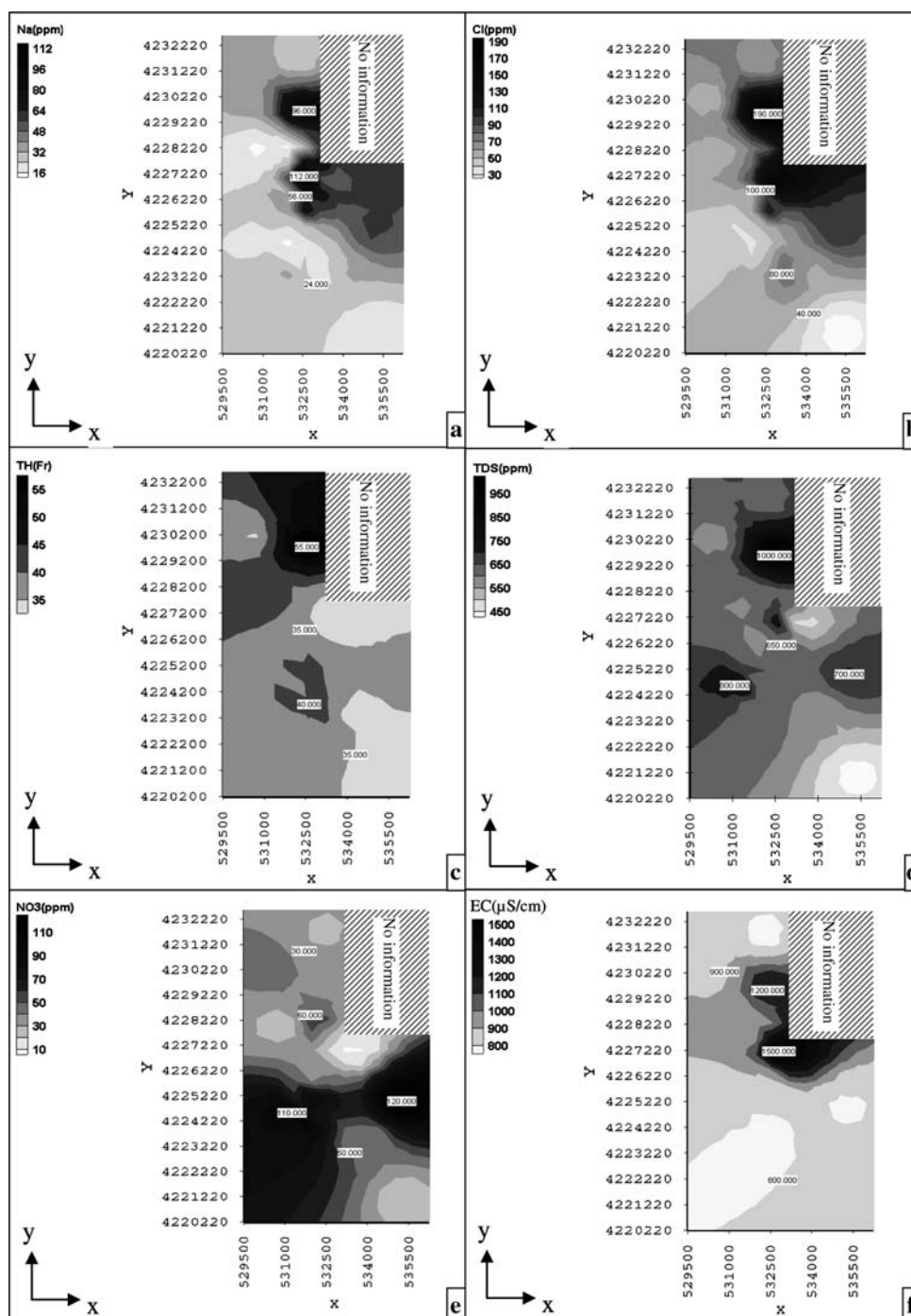
Total hardness values are observed between 29°F and 60°F. According to these results water can be classified as hard water. Figure 5c describes the contour map of total hardness in Torbali.

Ca^{2+} and Mg^{2+} concentrations vary between 67.8–220 and 23.9–43.0 ppm, respectively and maximum

concentrations for Ca^{2+} and Mg^{2+} are observed on north part while the minimum values are observed on south part of the region.

Potassium (K^+) concentration values are observed between 1.21 and 7.81 ppm in the groundwater samples and do not exceed the regulation values. The maximum and minimum values of K^+ are observed around the industrial area and agricultural area, respectively.

Fig. 5 Concentration maps for parameters



The maximum values of Iron (Fe^{2+}) and Manganese (Mn^{2+}) are 0.13 and 0.04 ppm, respectively. These values are within the maximum contaminant levels.

Concentrations of sulfate (SO_4^{2-}) vary between 31.9 and 242 ppm which are beneath the permissible limits according to drinking water standards. Minimum concentration value for SO_4^{2-} is observed on southeast part of the study area and maximum concentration is observed in the vicinity of the industrial area. pH values of the samples are nearly in the acceptable range for drinking water which is from 6.5 to 8.5.

Eh values which indicate a measurement of the oxidation potential of chemical reactions ranged from +278 to +528 mV. The maximum value is determined from the sample which is taken from the well on south part of the landfill area.

A high oxygen level observed values are between 4.45 and 9.95 ppm in the groundwater of Torbali on the west site of the Fetrek River.

According to analysis TDS and Nitrate (NO_3^-) concentrations exceed the permissible limits which were regulated by World Health Organization (WHO 1998) and Turkish Standards Institute (TSE 2005) for drinking water. The contour map of equal concentrations values for TDS and NO_3^- are given in Fig. 5d and e, respectively. High TDS concentrations are especially observed around the industrial area. When TDS values exceed 1,000 mg/l, water is considered unsafe for drinking purposes. At agricultural activities parts of the region NO_3^- concentrations are greater than the other parts of the study area with a value of higher than 100 ppm. NO_3^- contamination may also occur through industrial activities but only low contents of NO_3^- are observed around the industrial area in Torbali. Industrial activities having started 20 years ago, this may not be an enough long period to observe the whole effects of contamination.

The electrical conductivity values exceed the recommended limit but not the maximum contaminant level for drinking water. According to iso-lines for EC which is shown in Fig. 5f, the water in industrial area has high EC values.

The pie diagrams which indicate the local distribution of the ions are given in Fig. 6. There are not big differences depending on the locations of the samples.

Conclusion

Torbali region is at the edge of industrializations and faces several environmental threats. In this study groundwater sources in the Torbali region were examined.

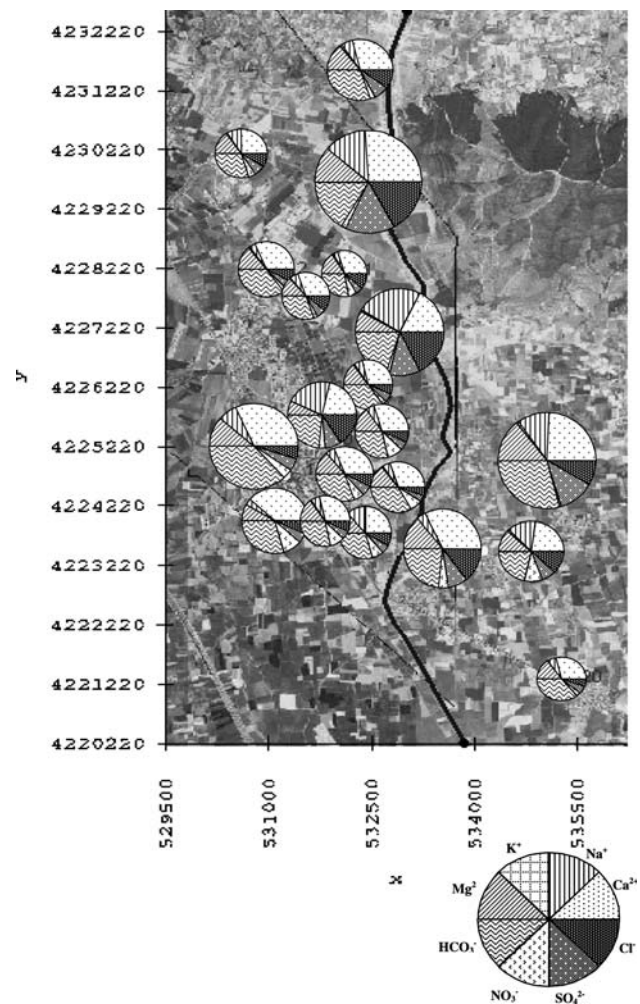


Fig. 6 Pie diagrams of the groundwater samples

Water samples which belong to wells used for drinking and domestic water purposes have high levels of NO_3^- , TDS and EC. On March 2002 (Kırer 2002) the average concentrations of NO_3^- , EC, Na^+ and Ca^{2+} were observed 25 ppm, 860 $\mu\text{S}/\text{cm}$, 30 ppm and 100 ppm, respectively. When the present results were compared with those of Kırer's study, a significant increase was observed.

Even with this increase of concentrations of some parameters the values have not reached very high values yet. Compare to other reports it is assumed that pollution level will keep increasing in the region in the future.

The maximum concentrations are generally observed around industrial area. The reason might be that an illegal wastewater discharges from factories to the Fetrek River. Taking into consideration the chemical analyses of leachate, which was done by Simsek (2002), the landfill area must be removed to more impervious area to prevent probable infiltrations

into the ground. A proper sewage and treatment systems must be established in the region as initial precautions.

References

- Ahn H-I, Chon H-T (1999) Assessment of groundwater contamination using geographic information systems. *Environ Geochem Health* 21:273–289
- Elhatip H, Afsin M, Kuscı I, Dirik K, Kurmac Y, Kavurmacı M (2003) Influence of human activities and agricultural on groundwater quality of Kayseri-Incesu-Dokuzpinar springs, central Anatolian part of Turkey. *Environ Geol* 44:490–494
- Kirer T (2002) Groundwater quality assessment in Torbali region. MS Thesis, Izmir Institute of Technology, Izmir, Turkey
- METU (Middle East Technical University 2000) Investigation of the groundwater resources of Kucuk Menderes River Basin. METU Department of Geological Engineering, Ankara, Turkey
- Melian R, Myrlian N, Gouriev A, Moraru C, Radstake F (1999) Groundwater quality and rural drinking-water supplies in the Republic of Moldova. *Hydrogeol J* 7:188–196
- Simsek C (2002) The hydrogeological investigations for the site selection of the landfill area of the Torbali Plain. PhD Thesis, The Graduate School of Natural and Applied Science, Dokuz Eylul University, Izmir, Turkey
- Singh KP, Malik A, Mohan D, Singh VK, Sinha S (2006) Evaluation of groundwater quality in northern Indo-Gangetic alluvium region. *Environ Monitor Assess* 112:211–230
- Turkish Standards Institute (2005) Water intended for human consumption. TS266. Ankara, Turkey
- Umar R, Ahmad MS (2000) Groundwater quality in parts of central Ganga Basin, India. *Environ Geol (Cases and Solutions)* 39(6)
- WHO (1998) Guidelines for drinking water quality. Addendum to vol 2, 2nd edn. Health criteria and other supporting information (WHO/EOS/98.1), World Health Organization, Geneva