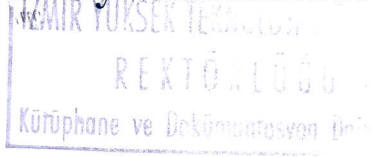


Groundwater Quality Assessment in Torbalı Region



By

Tuğba KIRER

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Requirements for the Degree of**

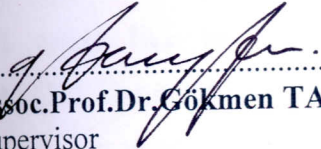
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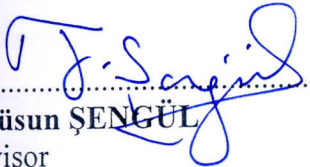
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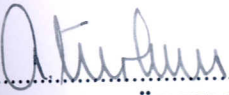
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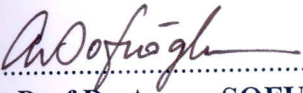
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ABSTRACT

Groundwater is an important source of irrigation, drinking water and other human activities. With the growth in population, agricultural and industrial activities and the groundwater usage have increased dramatically. However, not only the groundwater use, but also has the level of contamination in groundwater increased.

In Torbalı region, drinking water and irrigation water are supplied from wells which are drilled mostly without permission. Excessive abuse of fertilizers, and pesticides in agricultural activities and industries cause to contaminate the groundwater.

In order to investigate the quality of the groundwater in this region, sampling locations were determined taking the geology and industry of the region into account. The samples were collected monthly for ten months.

In this study, water quality parameters which are pH, temperature, electrical conductivity, calcium, magnesium, potassium, sodium, chloride, alkalinity, nitrate, nitrite, ammonia, copper, chromium, cadmium, lead, zinc, chemical oxygen demand (COD), and cyanide were examined to determine the groundwater quality and relationship between the parameters and the sources of contamination.

The samples were classified as hard water. All of the samples had bicarbonate alkalinity. The study revealed the existence of agricultural contamination. Nitrate concentrations of the groundwater samples increased in summer and the concentrations of nitrate were higher than the permissible limit in some of the wells. Heavy metal contamination was not detected in the region. The concentrations of the parameters were not constant during the monitoring study. This may be because the leachate of wastewaters which are discharged suddenly and discontinuously.

ÖZ

Yeraltısuyu, içme suyu, sulama suyu ve diğer faaliyetler için önemli bir kaynaktır. Nüfus artışıyla, tarımsal ve endüstriyel faaliyetler ve yeraltısuyunun kullanımı da aşırı bir şekilde artmıştır. Sadece yeraltısuyunun kullanımı artmakla kalmamış, yeraltısularının kirletilmesi de artmıştır.

Torbalı bölgesinde içme suyu ve kullanma suyu olarak kullanılan suyun büyük bir kısmı izinsiz olarak açılan kuyulardan karşılanmaktadır. Sanayiler ve tarımda pestisitlerin ve gübrelerin bilinçsizce kullanımı yeraltısu kaynaklarının kirlenmesine neden olmaktadır.

Bu çalışma yeraltısuyunun kalitesini ve kirliliğin nedenlerini ortaya çıkarmak için yeraltısuyu kalite parametrelerini, bu parametrelerin zaman içerisindeki değişimlerini incelemektedir. Bu parametreler pH, elektriksel iletkenlik, kalsiyum, magnezyum, potasyum, sodyum, bikarbonat, klorür, nitrat, nitrit, amonyak, siyanür, kimyasal oksijen ihtiyacı, bakır, çinko, kadmiyum, krom, ve kurşundur.

Kuyular geniş bir alanı kapsayacak şekilde bölgenin jeolojik özelliklerine ve endüstrilerin yerleşimine göre seçilmiştir. Torbalı bölgesinde, on ay boyunca on noktadan yeraltısu örnekleri alınmıştır.

Yapılan analizler sonucunda yeraltısu örnekleri sert su olarak sınıflandırılmıştır. Bu çalışma sonunda tarımsal faaliyetlerden kaynaklanan kirliliği tespit etmiştir. Nitrat konsantrasyonu yaz aylarında yükselmektedir ve bazı kuyularda izin verilen değerden fazladır. Bu bölgede ağır metal kirliliği tespit edilmemiştir. Çalışma sırasında izlenen her parametrenin konsantrasyonun sabit kalmadığı gözlenmiştir. Bu durumun nedeni, ani ve sürekli olmayan atıksu deşarjlarının yeraltısu kaynaklarına sızması ile açıklanabilir.

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CHAPTER I

INTRODUCTION

Clear, clean drinking water is what we expect when we turn on the tap. Groundwater generally supplies good quality water. It is an important source for more than half of the people in the world. It has numerous advantages over surface water. Groundwater is so essential to life. In many regions, groundwater is the principal and only water which feeds the plants which in turn feed animals and humankind. Groundwater, like any other resource, is not just of public health and economic value, it also has an important ecological function. The survival of natural habitats, and animal species depends on the availability of a sufficient quantity of good quality water. In some desert areas, groundwater has been the only source of water for millions of people.

It is usually more stable and reliable than any other source of water, but it is increasingly coming under threat because of greater demand. In some parts of the world, where lakes and rivers are drying out, it is the only reasonable alternative to dwindling supplies on the surface. The demand for groundwater is great and results from the general pattern of increased use of water for domestic, agricultural, and industrial purposes. The availability of groundwater and the suitability of its quality for different uses are inextricably intertwined. The quality and quantity of groundwater varies from place to place. The slow penetration of pollutants has been called a "chemical time bomb." It threatens humankind.

With the increase in world's population and as a result in pollution and wide-scale mismanagement of freshwater supplies, a critical water shortage may occur within the next 50 years. By 2025, the amount of water for use by each individual may be only half of what it is today, and today it is only half what it was in 1960. Once groundwater becomes contaminated, the options for treating it or for finding alternative supplies are to be very expensive and prospects for cleaning up an aquifer may be many years in the future.

Excessive withdrawal of groundwater, pollution, or mismanagement can deprive future generations from using the resource. It can cause drying out of wells and land subsidence.

Deep groundwater is relatively free from pollutants in many places and is excellent for drinking, domestic use and industrial purposes. But once an aquifer is contaminated, remedial measures can be long and costly, even impossible.

The objective of the study is to determine the groundwater quality, seasonal changes in groundwater quality, relationships between the quality parameters, and the sources of contamination in Torbalı region. Torbalı is rich in groundwater resources. In Torbalı region, large demand of drinking water and irrigation water are supplied from groundwater, so groundwater quality and changes of the quality are important. Considering to industrial activities, Torbalı is one of the developed cities of İzmir. Groundwater is widely used by industries in the region. Every factory and farm have private wells. Wells which are drilled without permission cause the depletion of groundwater. Pollution problems limit the usage of groundwater. In this study, in order to investigate the quality of groundwater in Torbalı region, samples were collected from 10 different sampling points which were chosen according to geological properties and the locations of industries. Therefore, the research covered a large area in Torbalı.

Because of the importance of the groundwater, there are many studies about groundwater quality in the world. For instance, a study conducted in northern part of Egypt, groundwater is characterized as good quality for different uses, because monitoring activities were applied in the area and monitoring programs show that groundwater is far from pollution (Soltan, 1997).

Rejinders *et. al.*, (1992) studied groundwater quality in the Netherlands. Groundwater samples were taken from about 600 locations. The samples were analyzed for components such as chloride, nitrate, sulfate, bicarbonate, ammonium, potassium, sodium, magnesium, calcium, iron, manganese, total phosphorous, dissolved organic carbon, pH, electrical conductivity, barium, strontium, zinc, aluminum, cadmium, nickel, chromium, copper, arsenic, lead, pesticides, organo (chloro) compounds and lanthanides. At the end of the study, NO₃-N and aluminum concentrations were found higher than the standards in the sandy areas.

Belgiorno *et. al.*, (2000) studied to investigate groundwater quality in a rural area in Italy over a 30 months period with 20 sampling points. The impact of the atmospheric pollution on water quality was also investigated in that study. According to the study, groundwater was found suitable for human use.

Groundwater quality was investigated in parts of Central Ganga Basin, India. Water samples were collected from shallow and deep aquifers and were analyzed for

major ions and trace elements. Trace elements studies of water from shallow aquifer showed that the concentration of toxic metals were above the permissible limits which may present a health hazard. The water from the deep aquifers was comparatively free of contamination (Umar *et al.*, 2000).

Aslan *et al.*, (2001) studied groundwater pollution in Urla and Menemen. In that study, pesticides and nitrate contamination were investigated in groundwater samples. Groundwater samples were taken from 28 wells. AOX was analyzed to detect pesticide concentration. According to the study, AOX was not detected, but nitrate concentration of the some of the groundwater samples exceeded the limit of WHO.

Eryurt and Sekin (2001) conducted a study to detect contamination of groundwater in Manisa. Nitrate, nitrite, ammonium, and hardness were determined in that study. Samples were taken in different periods from five deep water wells. According to the study, samples were hard and very hard. Nitrate concentration exceeded in one sample. Nitrite and ammonium concentrations did not exceed the limits. In the region, trace elements (Pb, Cd, As, Cr, Zn, Ba, Cu, Mn, Al, Fe) were also investigated. According to the study, all the parameters were under the permissible limits.

Polat and Yılmaz (2001) studied groundwater quality in Antalya. In that study, iron, manganese, organic matter, nitrate, phosphate, ammonia, microorganisms were investigated. According to the study, microbiological contamination was determined in the region. Organic matter contamination was not detected. Iron and manganese concentrations exceeded the limits in some water samples.

Özçelik and Sariiz (2001) studied groundwater quality in Eskişehir. In the study, the causes and distribution of groundwater contamination and its effects to the Eskişehir Plain were studied. According to the study, groundwater which is in an alluvium aquifer was contaminated with manure and chemicals by infiltration.

Turan *et al.*, (2001) studied to characterize groundwater in Çorlu region. In this study, nitrate, nitrite, sulfate, sulfite, sulfur, concentrations were under the permissible limits. Iron concentration was high and *Pasteurella* and *Acinetobacter* were determined in groundwater samples.

Asaroğlu *et al.*, (2001) studied to assess groundwater quality in some regions in İzmir (Buca, Konak, Narlıdere). The groundwater samples which were taken from 15 sampling point were examined monthly for one year. Some of the drinking water

quality criteria were detected. According to the study, organic matter, nitrite, and ammonia pollution were determined.

Kumbur *et. al.*, (1999) studied water quality in İçel. Dissolved oxygen, phosphate, nitrate, detergent, sulfate, suspended solid, chemical oxygen demand were analyzed. At the end of the study, there was no groundwater pollution in the region, but concentrations of the parameters were increasing.

In Turkey, although, there are some studies about the groundwater monitoring, another groundwater investigations should be applied in different areas.

This thesis contains eight chapter. Chapter I is Introduction. In Chapter II, what groundwater is and importance of groundwater were explained. Groundwater contamination and sources of contamination were described in Chapter III. Groundwater investigations and how an investigation study should be applied to a region was explained in Chapter IV. Meteorological, geological, hydrogeological properties of the region and agricultural and industrial activities, sampling points and possible sources of contamination were described in Chapter V. pH, temperature, electrical conductivity, calcium, magnesium, potassium, sodium, chloride, alkalinity, nitrate, nitrite, ammonia, copper, chromium, cadmium, lead, zinc, chemical oxygen demand (COD), and cyanide determination were also explained in Chapter V.

Temperature was determined in-situ. pH and electrical conductivity were determined immediately in laboratory. Bicarbonate was determined with titration method and chloride was analyzed with argentometric method. Nitrate was determined with cadmium reduction method by spectrophotometer, nitrite was analyzed with ferrous sulfate method by spectrophotometer, ammonia was determined with salicylate method by spectrophotometer, pyridine-pyrazalone method was used to detect cyanide, COD was examined with visible spectrophotometer by reactor digestion method. Major cations and Cu, Cr, Cd, Pb, Zn were analyzed with inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

The results were given in Chapter VI. The results of the analytical methods were tabulated and figured in the Chapter VI. Conclusion and recommendations for the region were given in Chapter VII.

CHAPTER II

GROUNDWATER

Groundwater is a large subsurface water reservoir. It contains over 95% of the fresh water resources and is an important reserve of good quality water (Figure 2.1 and Table 2.1). Natural sources of freshwater that become groundwater are areal recharge from precipitation that percolates through the unsaturated zone to the water table and losses of water from streams and other bodies of surface water such as lakes and wetlands. Areal recharge ranges from a tiny fraction to about one-half of average annual precipitation. Because areal recharge occurs over broad areas, even small average rates of recharge represent significant volumes of inflow to groundwater. Streams and other surface water bodies may either gain water from groundwater or lose water to groundwater. Streams are commonly significant sources of recharge to groundwater downstream from mountain fronts, steep hillslopes in arid and semiarid areas and in karst areas.

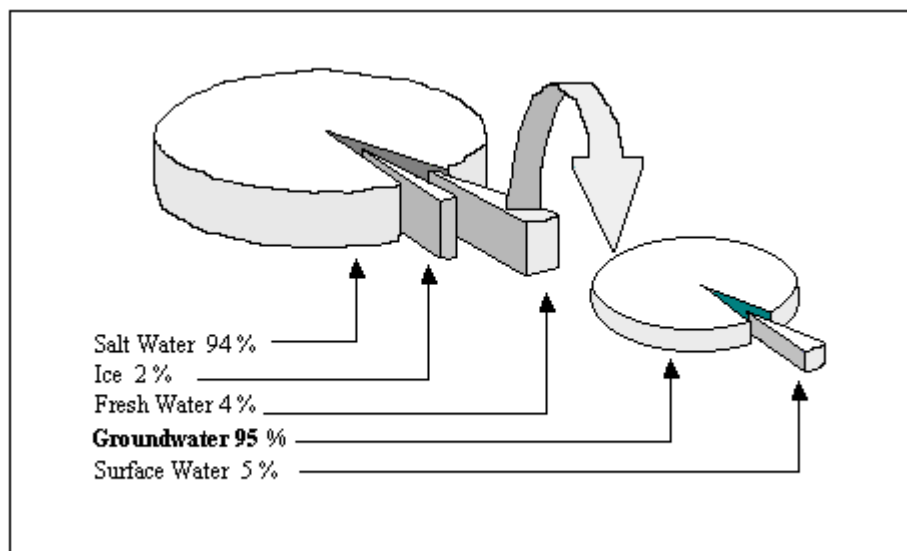


Figure 2.1. World water distribution

Table 2. 1. Estimate of the water balance of the world (Freeze and Cherry, 1979)

Parameter	Surface area (km ²) x 10 ⁶	Volume (km ³) x 10 ⁶	Volume (%)	Equivalent depth (m)	Residence time
Oceans, seas	361	1370	94	2500	~ 4000 years
Lakes	1.55	0.13	<0.01	0.25	~ 10 years
Swamps	<0.1	<0.01	<0.01	0.007	1-10 years
Rivers	<0.1	<0.01	<0.01	0.003	~ 2 weeks
Soil moisture	130	0.07	<0.01	0.13	2 weeks - 1 year
Groundwater	130	60	4	120	2 weeks -10,000 years
Icecaps	17.8	30	2	60	10-1000 years
Atmospheric water	504	0.01	<0.01	0.025	~10 days
Biospheric water	<0.1	<0.01	<0.01	0.001	~1 week

Groundwater is an important source of surface water, lakes and wetlands. It has advantages and disadvantages when comparing with surface water (Davis, 1991).

Advantages:

- Excellent quality can be used with no costly treatment or purification.
- Can be inexpensively tapped to the point of use, thereby saving the costs of transporting water to long distances.
- Costly storage facilities such as water tanks or towers are not needed.
- Passage through soil and granular materials allows the filtering of microorganisms and minute particles, as well as the attachment of organic compounds and some metals to clay minerals.
- Temperature and chemical quality are relatively constant.
- Some types of pollution, especially airborne contaminants are seldom concern.
- Spread of pollution is slow.
- Sediment content is generally negligible.
- Supply generally is unaffected by short-term fluctuations in climate.

The disadvantages of the groundwater comparing with surface water:

- Dissolved mineral content and hardness are higher than in nearby surface water.
- Once groundwater is contaminated, cleanup is slow and difficult.

A large ratio of total groundwater storage either to groundwater withdrawals by pumping or to natural discharge is one of the potentially useful characteristics of a groundwater system and enables water supplies to be maintained through long periods of drought. On the other hand, high groundwater use in areas of little recharge sometimes causes widespread declines in groundwater levels and a significant decrease in storage in the groundwater reservoir. Groundwater quality remediation projects generally are very expensive and rarely successful.

2.1. Hydrologic Cycle

The endless circulation of water between ocean, atmosphere, and land is called the hydrologic cycle (Figure 2.2). The hydrologic cycle is a major machine on the planet, controlling the distribution of water on the earth. Groundwater is one of the major links in the hydrologic cycle. Inflow to the hydrologic system arrives as precipitation, in the form of rainfall or snowmelt. Outflow takes place as stream flow or runoff and as evapotranspiration, a combination of evaporation from bodies of water, evaporation from soil surfaces, and transpiration from the soil by plants. Precipitation is delivered to streams both on the land surface, as overland flow to tributary channels; and by subsurface flow routes, as inter flow and base flow following infiltration into the soil (Freeze and Cherry, 1974).

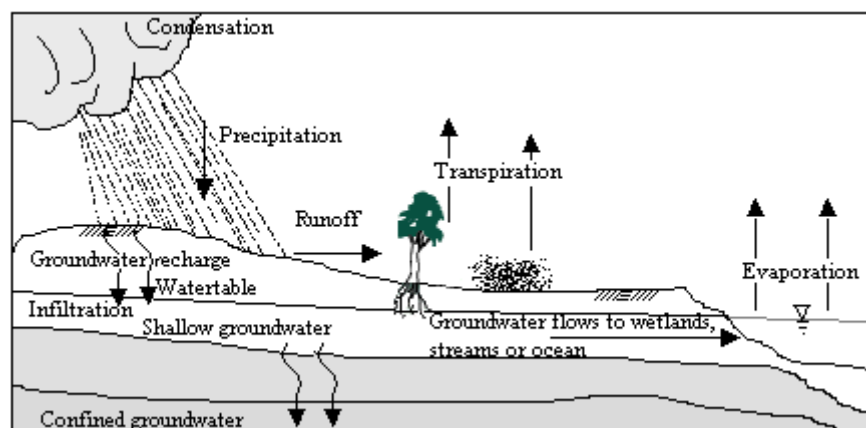


Figure 2.2. Hydrologic cycle

The annual average amount of rainfall is nearly 1000 mm in the world. In Turkey, annual average rainfall is 643 mm. This rainfall equals 501 km³ water of which 247 km³ evaporates, 41 km³ infiltrates to groundwater and 186 km³ flows to sea, ocean, or river (Figure 2.3). Turkey has 234 km³ sustainable water reserve which depends on meteorological conditions. But the amount of surface water and groundwater is estimated to be nearly 110 km³ (Figure 2.4). 98 km³ of the reserve is from rivers and 12 km³ of the reserve is from groundwater of which 6 km³ is used in Turkey (Kartal and Görkmen, 2001).

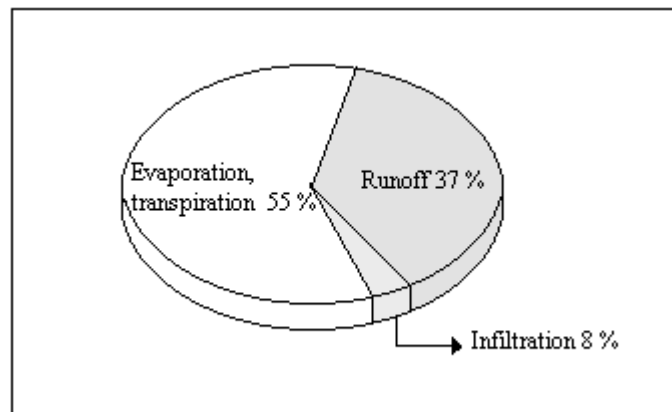


Figure 2.3. Annual hydrologic cycle in Turkey (Kartal and Görkmen, 2001)

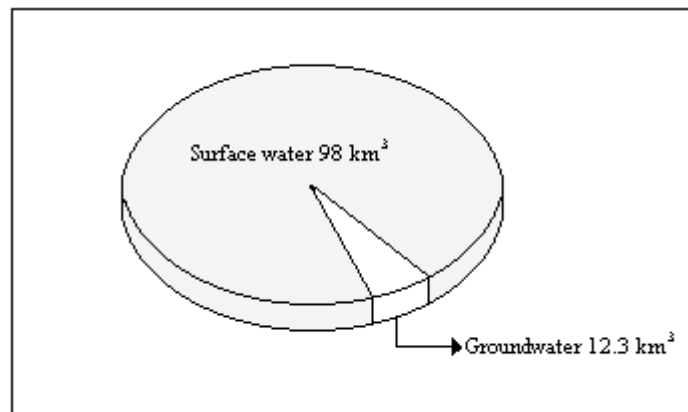


Figure 2.4. Amount of water in Turkey (Kartal and Görkmen, 2001)

2.2. Groundwater

Water beneath the land surface occurs in two principal zones, the unsaturated zone and the saturated zone. In the unsaturated zone, the spaces between particle grains and the cracks in rocks contain both air and water (Figure 2.5). Although a considerable amount of water can be present in the unsaturated zone, this water cannot be pumped by wells because of capillary forces holding it too tightly. In contrast to the unsaturated zone, the voids in the saturated zone are completely filled with water. The approximate upper surface of the saturated zone is referred to as the water table. Water in the saturated zone below the water table is referred to as ground water. Below the water table, the water pressure is high enough to allow water to enter a well as the water level in the well is lowered by pumping, thus permitting groundwater to be withdrawn for use. Between the unsaturated zone and the water table there is a transition zone, called the capillary fringe. In this zone, the voids are saturated or almost saturated with water that is held in place by capillary forces (Figure 2.6).

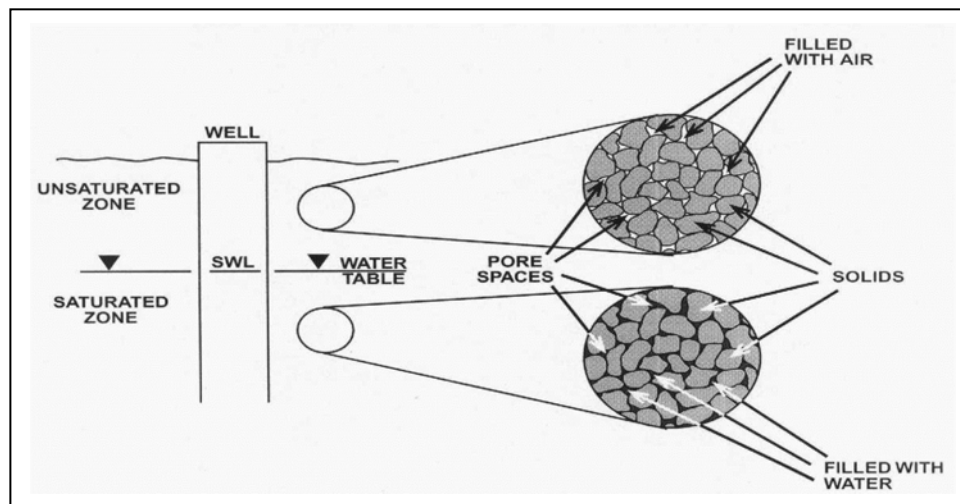


Figure 2.5. Occurrence of groundwater in saturated zone and unsaturated zone

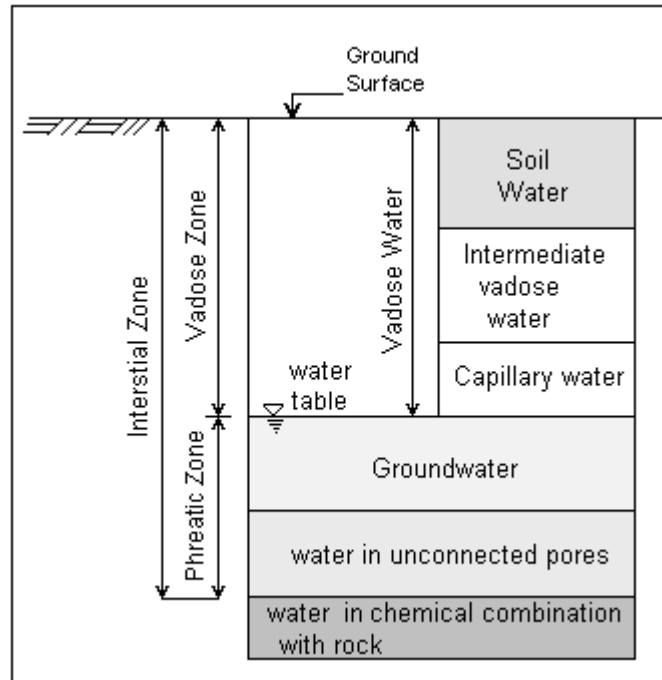


Figure 2.6. Groundwater conditions near the ground surface

Earth materials vary widely in their ability to transmit and store groundwater. The ability of earth materials to transmit groundwater (quantified as hydraulic conductivity) varies by orders of magnitude and is determined by the size, shape, interconnectedness, and volume of spaces between solids in the different types of materials. For example, the interconnected pore spaces in sand and gravel are larger than those in finer grained sediments, and the hydraulic conductivity of sand and gravel is larger than the hydraulic conductivity of the finer grained materials. The ability of earth materials to store groundwater also varies among different types of materials.

There are three basic types of geologic materials through which groundwater normally flows. These are, porous media, fractured media, and fractured porous media. In porous media (e.g., sand and gravels, silt, loess, clay, till, and sandstone), groundwater and contaminants move through the pore spaces among individual grains (Figure 2.7.a). In fractured media (e.g., dolomites, some shales, granites, and crystalline rocks), groundwater and contaminants move predominantly through cracks or solution crevices known as impermeable rock (Figure 2.7.b). In fractured porous media (e.g., fractured tills, fractured sandstone, and some fractured shales), groundwater and contaminants can move through both the intergranular pore spaces and cracks or crevices in the rock or soil (Figure 2.7.c). The occurrence and movement of

groundwater through pores and cracks or solution crevices depend on the relative effective porosity and degree of channelling occurring in cracks or crevices. The distribution of basic types of geologic materials is seldom homogeneous or uniform. In most settings, two or more types of materials are present. Even for one type of material at a given site, large differences in hydrologic characteristics may be encountered.

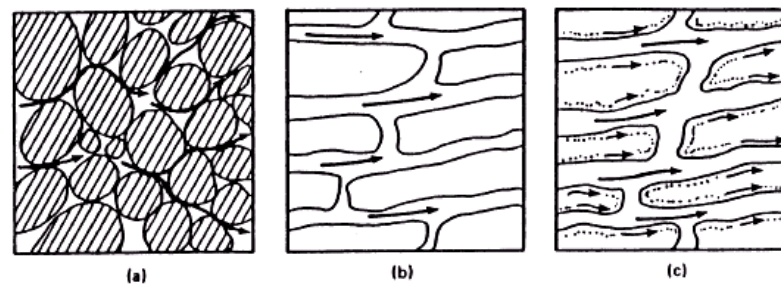


Figure 2.7. Occurrence and movement of groundwater and contaminants through a) porous media, (b) fractured or creviced media, (c) fractured porous media. (EPA, 1989)

Velocities of groundwater flow are generally low and in the order of magnitude of less than velocities of stream flow. The movement of groundwater normally occurs as slow seepage through the pore spaces among particles of unconsolidated earth materials or through networks of fractures and solution openings in consolidated rocks. A velocity of 30 cm per day or greater is a high rate of movement for groundwater, and groundwater velocities can be as low as 30 cm per year or 30 cm per decade. In contrast, velocities of stream flow generally are measured in meter per second. The low velocities of groundwater flow can have important implications, particularly in relation to the movement of contaminants.

Wells are the principal direct window to study the subsurface environment. Not only are wells used to pump groundwater for many purposes, they but also provide essential information about conditions in the subsurface. Wells;

- allow direct measurement of water levels in the well,
- allow sampling of groundwater for chemical analysis
- provide access for a large array of physical measurements in the borehole that give indirect information on the properties of the fluids and earth materials in the neighborhood of the well,
- allow hydraulic testing of the earth materials in the neighborhood of the well to determine local values of their transmitting and storage properties.

In addition, earth materials can be sampled directly at any depth during the drilling of the well. Pumping groundwater from a well always causes;

- a decline in groundwater levels at and near the well.
- a diversion of groundwater to the pumping well that was moving slowly to its natural, possibly distant, area of discharge.
- a local effect on the groundwater flow system.
- A regional effect large areas when many wells are pumped.

2.2.Constitutes of Groundwater

Water is never found in a pure state in nature. Groundwater may contain many constituents, including microorganisms, gases, inorganic and organic materials. As a result of chemical and biochemical interactions between groundwater and the geological materials through which it flows, and to a lesser extent because of contributions from the atmosphere and surface water bodies, groundwater contains a wide variety of dissolved inorganic chemical constituents in various concentrations. It can be viewed as an electrolyte solution because nearly all its major and minor constituents are present in ionic form (Freeze and Cherry, 1979).

2.2.1.Naturally Occurring Inorganic Chemicals

Groundwater generally contains more dissolved minerals than nearby streams, although its origin is precipitation. Water passing through the soil dissolves large amounts of carbon dioxide generated by soil microorganisms decomposing organic matter. This carbon dioxide is dissolved in soil moisture, producing a weak carbonic acid solution that attacks carbonate and silicate minerals of calcium, magnesium and sodium, causing their solution. Groundwater also stays in contact with the surrounding rocks much longer than surface water, which allows more time for chemical reactions to occur. This dissolution process continues until chemical equilibrium is reached between the water and the minerals with which it is in contact (Freeze and Cherry, 1979). Average compositions of major elements and selected trace metals in igneous and some sedimentary rocks are listed in Table 2.2.

Table 2.2. Inorganic constituents of groundwater (Bedient, Rifai, and Newell, 1999).

Major Dissolved Inorganic Constituents (1.0 to 100 mg/L)		
Bicarbonate	Silicon	Magnesium
Calcium	Sodium	Carbonic Acid
Chloride	Sulphate	
Minor Dissolved Inorganic Constituents (0.01- 10 mg/L)		
Boron	Iron	Strontium
Carbonate	Nitrate	Potassium
Fluoride		
Trace Dissolved Inorganic Constituents (Less than 0.1 mg/L)		
Aluminium	Germanium	Rubidium
Antimony	Gold	Ruthenium
Arsenic	Indium	Scandium
Barium	Iodide	Selenium
Beryllium	Lanthanum	Silver
Bismuth	Lead	Thallium
Bromide	Lithium	Thorium
Cadmium	Manganese	Tin
Cerium	Molybdenum	Titanium
Cesium	Nickel	Tungsten
Chromium	Niobium	Uranium
Cobalt	Phosphate	Vanadium
Copper	Platinum	Zinc
Gallium	Radium	Zirconium

2.2.2. Naturally Occurring Organic Constituents

Dissolved organic matter is ubiquitous in natural groundwater, although the concentrations are generally low compared to the inorganic constituents. Dissolved organic substances which are referred to as humic and fulvic acids, are of little concern from a water quality view point (Freeze and Cherry, 1979). Infiltrating water carries organic matter from the soil down to the groundwater. Organic acids formed through the decay of organic matter bacteria, fungi and viruses may be leached to the groundwater. These natural organic compounds and living organisms are attached to or filtered out by mineral grains (Davis, 1991). Fulvic acid plays a major role in the transport and deposition of Fe, and Al in soils (Langmiur, 1997).

The most abundant dissolved gases in groundwater are N₂, O₂, CO₂, CH₄, H₂S, and N₂O. The first three make up the earth's atmosphere and it is, therefore not surprising that they occur in subsurface water. CH₄, H₂S, and N₂O can often exist in groundwater in significant concentrations because they are the biochemical processes that occur in non-aerated subsurface zones. This generally limits the possibility for appreciable migration of large quantities in groundwater. They can limit the usefulness of groundwater and in some cases, can even cause major problems or even hazards.

2.3. Groundwater Quality

It is important to evaluate water as having two separate characteristics: purity and quality. It is considered that purity is a function of water quality. Water might be crystal clear, cold, and even free-running, but might still contain pathogens, microbes, and bacteria injurious to one's health. The earth is a tremendous filter and purifier. However, this is never, ever a sure thing (Max and Charlotte, 1991). Various parameters of water quality such as taste, odor, microbial content, and dissolved concentrations of naturally occurring chemical constituents define the suitability of water for different uses.

Natural quality reflects the types and amounts of soluble and insoluble substances with which the water has come in contact. It is often assumed that natural groundwater quality is nearly constant at any particular site. Field data substantiate this assumption, and logic leads to the same conclusion, if the aquifer is confined and not subjected to a stress. Deeper or confined aquifers in which groundwater flow is lethargic, generally have a nearly constant chemical quality that, at any particular place, reflects the geochemical reactions that occurred as the water migrated through confining

layers and aquifers to points of collection or discharge. The quality of deeper water can change, but generally not abruptly, in response to stress on the aquifer system. In contrast to confined aquifers, groundwater quality, in shallow and surficial aquifers can change considerably within a few days. These aquifers are not well protected from changes brought about by natural events occurring at the land surface or from human induced contamination (EPA, 1988).

CHAPTER III

GROUNDWATER CONTAMINATION

As water moves through hydrologic cycle, its quality changes in response to differences in the environments through which it passes. The changes may be either natural or human-influenced, in some cases they cannot, but in most instances they can be managed in order to limit adverse water quality changes.

Fortunately, there are several mechanisms that tend to prevent or retard the migration of most organic substances from the land surface or soil zone into deeper parts of the subsurface environment (EPA, 1988):

1. Physical-chemical characteristics of the earth materials through which the liquid wastes flow. To a large extent, it is the aquifer framework that controls the movement of groundwater and contaminants. The geologic framework, in conjunction with surface topography, also exerts a major control on the configuration of the water table and the thickness of the unsaturated zone. The position of the water table is important not only because it is the boundary between the saturated and unsaturated zones, but also because it marks the bottom and, therefore, the thickness of the unsaturated material.

2. Natural processes that tend to remove or degrade a contaminant as it flows through the subsurface from areas or points of recharge to zones or points of discharge. These processes include filtration, sorption, dispersion, oxidation, microbial degradation, chemical precipitation, chemical degradation, volatilization, biological uptake, and dilution.

3. Hydraulics of the flow system through which the waste migrates beginning with infiltration and ending with discharge. Primarily hydraulic conductivity is important. The contaminant may enter an aquifer directly, by flowing through the unsaturated zone, by interaquifer leakage, by migration in the zone of saturation, or by flow through open holes.

4. Nature of the contaminant. This includes its physical, chemical, and biological characteristics and particularly its stability under various conditions.

3.1.Sources of Groundwater Contamination

3.1.1.Natural Sources

Groundwater commonly contains one or more naturally occurring chemicals, leached from soil or rocks by percolating water, in concentrations that exceed drinking water standards. One of the most common water quality concerns is the presence of dissolved solids and chloride. Although not particularly toxic, iron and manganese in concentrations greater than the limits can impair the taste of water; stain plumbing fixtures, glassware and laundry; and reduce well-pumping efficiency. Dissolved gases can have a significant influence on the subsurface hydro-chemical environment. They can limit the usefulness of groundwater and, in some cases can even cause major problems or even hazards (Freeze and Cherry, 1979).

Possible natural contaminants include trace elements such as arsenic and selenium, radionuclides such as radon, and high concentrations of commonly occurring dissolved constituents.

3.1.2.Anthropogenic Sources

Virtually, any human activity near the land surface can be a source of contaminants to groundwater as long as water and possibly other fluids move from the land surface to the water table (Figure 3.1).

Contaminants can enter groundwater from different generic sources related to human activities. These sources are commonly referred to as either point or non-point sources. Point sources are localized in areas of an acre or less, whereas non-point sources are dispersed over broad areas. Non-point source leaching is more difficult to control because;

- it can be widespread but it does not occur all agricultural land, and where it does occur, it is often at very low levels.
- the sources and the leaching behavior of some materials are not well understood.
- it can occur even where agricultural practices are designed to minimize soil and water degradation.

The most common sources of human-induced groundwater contamination can be grouped into five categories:

- Waste disposal practices
- Storage and handling of materials and wastes
- Agricultural activities
- Saline water intrusion
- Accidental spill.

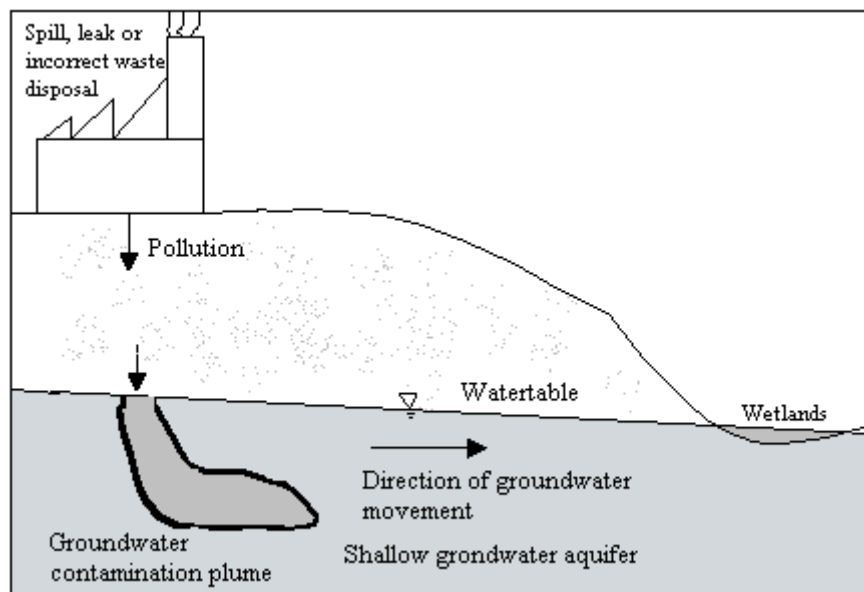


Figure 3.1. Groundwater pollution

3.1.2.1. Waste Disposal Practices

The best known sources of groundwater contamination are associated with the storage or disposal of liquid and solid wastes. The organic substances most frequently reported in groundwater as resulting from waste disposal, in decreasing order of occurrence, are trichloroethylene (TCE), chloroform, benzene, pentachlorophenol, tetrachloroethylene (PCE), creosote, phenolic compounds, 1,1,1-trichloroethane, toluene, xylene. Waste disposal can take a number of forms:

- Septic systems
- Municipal and industrial landfills
- Direct application of stabilized wastes to the land
- Surface impoundment
- Waste-injection wells

3.1.2.1.1. Septic Systems

Septic systems are the largest source by volume of waste discharged to the land. Septic systems present unique and potentially more severe problems to groundwater contamination than domestic systems due to the hazardous nature of the wastes disposed of in these systems. These systems are sources of fecal coliforms, nitrates and nitrites, ammonia, phosphorus, chloride, and organic substances.

3.1.2.1.2. Waste-injection Wells

Injection wells are used to discharge liquid hazardous waste, agricultural and urban runoff, municipal sewage, aquifer recharge water and fluids in solution mining and oil recovery into the subsurface. If the fluid enters a drinking water aquifer by faulty construction, or inadequate understanding of the geology, injection wells can cause groundwater contamination.

3.1.2.1.3. Surface Impoundment

Surface impoundment, including ponds and lagoons, generally consists of relatively shallow excavations that range in area from a few square meter to many square meters (EPA, 1988). Surface impoundments are used to store, treat or dispose of oil and gas brines, acidic mine wastes, industrial wastes, animal wastes, municipal treatment plant sludge and cooling water.

3.1.2.1.4. Municipal and Industrial Landfills

Landfills are built with elaborate leak-prevention systems, but most particularly the older ones, are simply large holes in the ground filled with waste and covered with dirt. Originally designed to reduce air pollution and unsightly trash that accompanied open dumping and burning, landfills became the disposal method for every conceivable type of waste. However, many were poorly designed and are leaking liquids or leachates, which are contaminating surrounding shallow groundwater (Bedient, Rifai, and Newell, 1999).

3.1.2.1.5.Land Application

In many places, solid and liquid wastes are placed or sprayed on the land, commonly after treatment and stabilization. Land application of wastewater and sewage sludge is an alternative to conventional treatment and disposal, and is common usage by the vegetable industry, petroleum refining, pulp and paper, and the power industry.

3.1.2.2.Storage and Handling of Materials

A growing problem of substantial potential consequence is leakage from underground storage tanks and from pipelines. These facilities store billions of gallons of liquids that are used for municipal, industrial, and agricultural purposes. Corrosion is the most frequent cause for leakage. Gasoline leakage causes severe hazardous difficulties.

3.1.2.3.Agricultural Activities

Agriculture is one of the most widespread human activities that affects the quality of groundwater. Fertilizers and pesticides which are used widely in agriculture are highly toxic and quite mobile in the subsurface. Numerous compounds, however, can quickly attach to fine-grained sediment, such as organic matter and clay and silt particles. In many fertilized areas, the infiltration of nitrate a decomposition product of ammonia fertilizer adversely affects groundwater.

The usage of groundwater in agriculture can be contaminate soil. The reason of the contamination is the usage of poor quality water in irrigation.

The depletion of groundwater causes to decrease to capacity of water reserves. The run out of the water causes to squeeze the geological materials so pores and holes that hold water can be collapsed.

3.1.2.4.Accidental Spills

A large volume of toxic materials is transported by truck and stored in tanks. Accidental spills of these materials are common. Accidental spills occur in large amounts each year, and these include hydrocarbons, paint products, flammable materials, acids etc. Virtually, no methods are available to quickly and adequately clean up an accidental spill or those caused by explosions or fires (EPA, 1988)

There are many causes of the groundwater contamination, but leachate is the source that needs special consideration. It is more likely to be attenuated by microbial

degradation, sorption, dilution, and dispersion. The physical, chemical, and biological characteristics of leachate are influenced by the composition of the waste, the stage of decomposition, microbial activity, the chemical and physical characteristics of the soil cover and of the landfill, and the time rate of release (EPA, 1988).

3.5. Monitoring and Indicator Parameters to Ascertain Contamination

Groundwater quality parameters and the contaminants should be monitored in monitoring studies. According to Table 5.1, possible contaminants which were monitored in the study were chosen for Torbalı region. These parameters are pH, electrical conductivity, temperature, calcium, magnesium, sodium, potassium, alkalinity, chloride, nitrate, nitrite, ammonia, cyanide, chromium, cadmium, copper, lead, zinc, and chemical oxygen demand.

The pH of an aqueous system is a measure of the acid-base equilibrium achieved by various dissolved compounds and, in most natural waters, is controlled by the carbon dioxide-bicarbonate-carbonate equilibrium system. This system involves various constitutes equilibria, all of which are affected by temperature. In water with a buffering capacity imparted by bicarbonate, carbonate, and hydroxide ions. The pH of most raw water sources lies within the range 6.5-8.5 . A direct relationship between human health and the pH of drinking water is impossible ascertain because pH is so closely associated with other aspects of water quality (WHO, 1984).

Hardness in water is caused by dissolved calcium and, to a lesser extent, by magnesium. It is usually expressed as the equivalent quantity of calcium carbonate.

Nitrates in groundwater represent a widely distributed pollution concern. Nitrates are perhaps the most ubiquitous of all groundwater contaminants. Nitrate is very soluble and mobile in water (Figure 3.2). The key concern regarding usage of groundwater with excessive concentration of nitrates is related to human health effects, particularly with regard to infants. The major effects are associated with losses in oxygen transport/transfer capabilities in the blood. Nitrate comes from nitrogen, a plant nutrient supplied by inorganic fertilizer and animal manure. Additionally, airborne nitrogen compounds given by industry and automobiles are deposited on the land, in precipitation, and in dry particles. In agricultural areas in which nitrate manures are applied irrigation causes to the leakage of nitrate. Therefore, nitrate can reach to groundwater. Other nonagricultural sources of nitrate include lawn fertilizers, septic systems, and domestic animals in residential areas.

Ammonia is present naturally in surface and waste waters. Its concentration generally is low in groundwaters because it adsorbs to soil particles and clays and is not leached readily from soils. It is produced largely by deamination of organic nitrogen-containing compounds and by hydrolysis of urea.

Nitrite is an intermediate oxidation state of nitrogen, between the oxidation of ammonia to nitrate and in the reduction of nitrate. Nitrite can enter a water supply system through its use as corrosion inhibitor in industrial process water. Nitrite is the actual etiologic agent for methemoglobinemia.

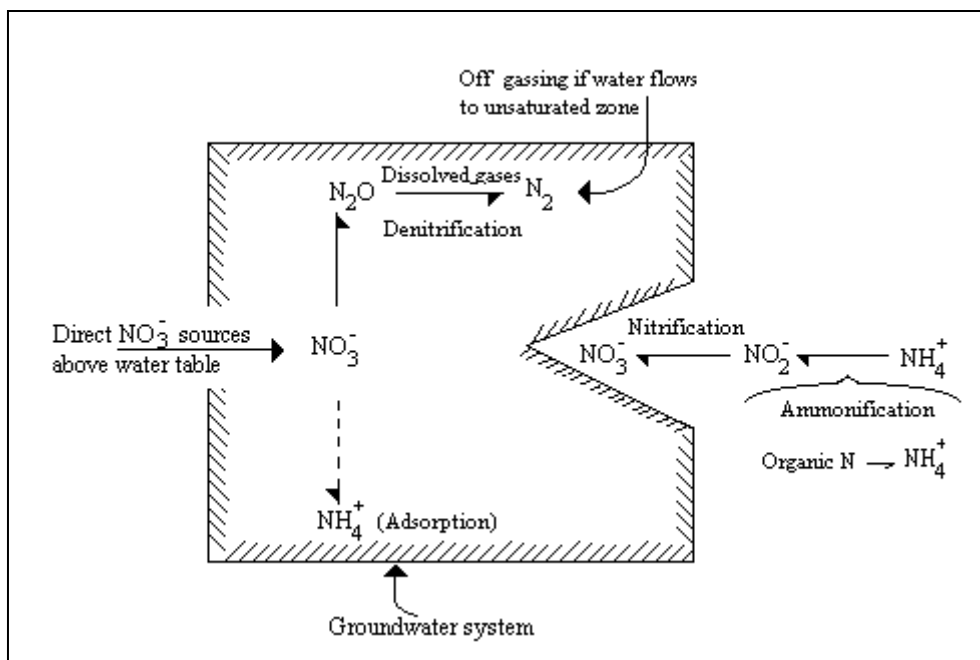
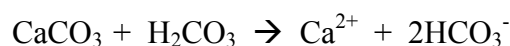


Figure 3.2. Nitrogen transformation in the groundwater system (Freeze and Cherry, 1979)

Alkalinity is the capacity of water to react with hydrogen ions. Alkalinity caused principally not only by the presence in water of the bases HCO₃⁻, CO₃²⁻, OH⁻ but also by smaller concentrations of silicates, borate, ammonia, phosphate, and organic bases. The alkalinity of a water has little public health significance. Highly alkaline waters are usually unpalatable, and consumers tend to seek other supplies (Dajlido and Best, 1993). Bicarbonate alkalinity is only found in groundwater samples. It can be explained by the following reaction.



Chloride is one of the major inorganic anions in water and wastewater. The chloride content normally increases as the mineral content increases. It is generally in the form of sodium, potassium, and calcium salts. In many areas, the level of chlorides in natural waters is an important consideration in the selection of supplies for domestic, industrial, agricultural use. The chloride determination is used to control pumping of groundwater from locations where intrusion of seawater is a problem. Chloride can interfere in the determination of chemical oxygen demand when the concentration of chloride is higher than 1000 mg/L.

In general, the levels of cyanide in raw water appear to be below except in the cases of serious contamination, mainly by industrial discharges to river or other sources. Metal treating industries, coke and gas manufacture, and a variety of chemical producers can be major sources of cyanide contamination of water (WHO, 1984).

Heavy metal concentration of groundwater increase with the infiltration of waste waters to groundwater. Industrial applications and their wastewater should be investigated in the monitoring area. Groundwater quality also should be investigated to check the existence of leakage from the industries. Heavy metals can be found in groundwater by natural and/or anthropogenical. The naturally occurring heavy metals are in trace amounts in groundwater. The permissible limits and the average concentration of the naturally occurring elements are given in Table 3.1 and Table 2.2.

Zinc is an abundant element and constitutes approximately 0.004 percent of the earth's substance. Zinc is an essential element and is generally considered to be non-toxic. The carbonates, oxides, and sulfides of zinc are sparingly soluble, and therefore zinc is present in natural waters at low concentration. Drinking water is not regarded as an important nutritional source of this element. Water containing zinc at concentration above 5.0 mg/L tends to be opalescent, developing a greasy film when boiled, and having an undesirable astringent taste. Zinc uses range from metal products to rubber and medicines. Zinc used to protect iron and steel from corrosion (galvanized metal), as alloying metal to make bronze and brass, as zinc-based die casting alloy, and as rolled zinc. Zinc compounds are consumed mainly by the rubber, chemical, paint, and agricultural industries.

Chromium can exist in valences from -2 to 6 but is present in the environment mainly in the trivalent or hexavalent state. Trivalent chromium (Cr (III)) is the most common naturally occurring state; most soils and rocks contain small amounts of chromic oxide (Cr₂O₃). Most of the chromium in soils is present in the form of highly

insoluble chromites. Weathering, oxidation, and bacterial action convert these chromites into soluble forms, and in this way chromium mineral deposits contribute slightly to the chromium content of natural waters. Cr is widely used in industry. Chromium has a wide range of uses in metals, chemicals, and refractories. Chromium use in iron, steel, and nonferrous alloys enhances resistance to corrosion and oxidation. The use of chromium to produce stainless steel and nonferrous alloys are two of its more important applications. Other applications are in alloy steel, plating of metals, pigments, leather processing, catalysts, surface treatments, and refractories.

Cadmium is relatively rare element. It is uniformly distributed in the earth's crust at an average concentration of between 0.15 and 0.2 mg/L. Cadmium occurs in nature in the form of various inorganic compounds and as complexes with naturally occurring chelating agents. Cadmium metal is used in the steel industry and in plastics. Cadmium compounds are widely used in batteries. Cadmium is released to the environment in wastewater, and diffuse pollution is caused by contamination from fertilizers and local air pollution. Contamination in drinking-water may also be caused by impurities in the zinc of galvanized pipes and solders and some metal fittings, although levels in drinking-water are usually less than 1 µg/L. Food is the main source of daily exposure to cadmium.

Lead is the most common of the heavy metals. Lead is rarely found as the free metal in nature. It has many applications in industry. Lead exists in the oxidation states Pb^{2+} and Pb^{4+} , with divalent form being the more stable in most aquatic environments. The speciation of lead compounds in water is complicated and depends on a number of factors, principally pH, dissolved oxygen, and the concentration of other organic and inorganic compounds. Lead is highly toxic and is also considered a probable carcinogen (Dajlido and Best, 1993).

Copper and its compounds are used in electrical wiring, water pipes, cooking utensils, and electroplating, and as algicides and food additives. Copper concentrations in drinking water vary widely as a result of variations in pH, hardness, and copper availability in the distribution system. Levels of copper in running water tend to be low, whereas those of standing or partially flushed water samples are more variable and can be substantially higher, particularly in areas where the water is soft and corrosive.

Table 3. 1.The maximum concentrations of the parameters which were regulated by Environmental Protection Agency , Turkish Standards and European Union.

Parameter	TS*		EPA**	EU***
	Drinking	Irrigation		
pH	5.5-8.5	6.0-9.0	6.5-8.5	6.5-8.5
Conductivity (µS/cm)	Not regulated	2000-3000	Not regulated	400
Chloride (mg/L)	250.0	626.0-710.0	250.0	250.0
Calcium (mg/L)	100.0	Not regulated	Not regulated	100.0
Magnesium (mg/L)	50.0	Not regulated	Not regulated	50.0
Sodium (mg/L)	175.0	Not regulated	Not regulated	150.0
Potassium (mg/L)	12.0	Not regulated	Not regulated	12.0
Nitrate (mg/L)	45.0	30.0-50.0	45.0	50.0
Cyanide (mg/L)	0.05	Not regulated	0.2	0.05
COD (mg/L)	10.0	Not regulated	Not regulated	Not regulated
Cadmium (µg/L)	3.0	10.0	5.0	5.0
Chromium (µg/L)	50.0	100.0	100.0	50.0
Copper (mg/L)	1.5	5.0	1.3	0.1
Lead (µg/L)	10.0	10.0	0	10.0
Zinc (µg/L)	3.0	10.0	5.0	0.1

* Turkish Standards

**Environmental Protection Agency (National Primary Drinking Water Regulations and National Secondary Drinking Water Regulations)

*** European Union (80/77/EEC)

CHAPTER IV

GROUNDWATER INVESTIGATIONS

4.1. Groundwater Quality Monitoring

Groundwater investigations are conducted for various purposes:

- Establishment of background quality.
- Detection of processes, and sudden changes in water quality.
- Identification of areas, additional research, or legal and educational aims.

The objective of initial monitoring is to verify or to begin characterising known or suspected contaminant releases to groundwater. To help to accomplish this objective, any existing monitoring wells should be evaluated to provide samples representative of groundwater quality. If a comprehensive work plan is not developed before the monitoring project is initiated, or it is not followed, many field investigations would be inadequate and costly.

Monitoring of groundwater contaminants in aquifers is complex. Because, it involves a variety of contaminants originated from different sources; it requires an understanding of the behavior of different components of many contaminants, it involves various systems and, groundwater contaminants and polluted leachates may be present in both the vadose and the saturated zones. The distribution of microorganisms in polluted groundwater and in polluted leachates also contributes to complexity of monitoring. In addition monitoring is complex because it deals with dynamic relationship between the fractions of moving and immobile parts of the liquid that do not interact with the porous formations (Zoller, 1994).

The designing strategy of the monitoring program depends mainly on the following factors:

- Quantity and quality of the existing records regarding the nature of the aquifer geology,
- Characteristics of the contaminants generated by various sources,
- Groundwater regime,
- Available financial resources,
- The political boundaries of the area.

In addition, the design of monitoring should take into account the vulnerability of the aquifer. For a shallow, unconfined or karstic aquifer, a more intensive monitoring program must be established to use the data obtained as inputs to programs that evaluate the need for, and the effectiveness of surface and subsurface management models and techniques.

Groundwater investigations can be divided into three general types (EPA,1988):

1. Regional investigations: It may encompass several hundred or even thousands of square meters. It is reconnaissance of the groundwater and used to obtain an overall evaluation of the groundwater situation.
2. Local investigation: It is conducted in the vicinity of a contaminated site. It may cover a few tens or hundreds of square meters, and used to determine local groundwater conditions.
3. Site evaluation: It is ascertain, with considerable degree of certainty, the extent of contamination, its source or sources, hydraulic properties, and velocity, as well as of the other related controls on contaminant migration.

Direct and indirect methods are used for a monitoring activity. Monitoring procedures should include direct methods of obtaining groundwater quality information (e.g., sampling and analysis of groundwater from monitoring wells). Indirect methods of investigation may also be used when appropriate to aid in determining locations for monitoring wells (i.e., through geologic and/or geochemical interpretation of indirect data). For many cases, the use of both direct and indirect methods may be the most efficient approach (EPA, 1989).

Groundwater monitoring program should be applied according to following steps:

- Establishment of objectives,
- Preparation of work plan,
- Data collection and interpretation,

Monitoring frequency should be based on various factors, including:

- Groundwater flow rate and flow patterns
- Adequacy of existing monitoring data
- Climatological characteristics

Generally, the greater the rate of groundwater flow, the greater the monitoring frequency needed.

The heterogeneity of the materials can play a significant role in the rate of contaminant transport, as well as in developing appropriate monitoring procedures for a site. Once the geologic setting is understood, the site hydrology should be evaluated. The location of the site within the regional groundwater flow system, or regional flow net, should be determined to evaluate the potential for contaminant migration at the regional scale. The potential dimensions of a contaminant release depend on a number of factors including groundwater recharge and discharge patterns, net precipitation, topography, surface water body locations, and the regional geologic setting. Groundwater flow paths, and where possible, generalised flow nets are shown to put over on cross-sections of the geological units.

Hydrogeologic conditions at the site to be monitored should be evaluated for the potential impacts the setting may have on the development of a monitoring program and the quality of the resulting data. Several hydrogeologic parameters should be evaluated, including; types and distribution of geologic materials, occurrence and movement of groundwater through these materials, location of the facility with respect to the regional groundwater flow system, relative permeability of the materials and potential interactions between contaminants and the geochemical parameters within the formations of interest.

In order to adequately characterise the hydrologic setting of a site, an analysis of site geology should first be completed. Geologic site characterisation consists of both a characterisation of stratigraphy, which includes unconsolidated material analysis, bedrock features such as lithology and structure, and depositional information, which indicates the sequence of events which resulted in the present subsurface configuration. Information that may be needed to characterise a site's subsurface geology includes grain size distribution and gradation, porosity, discontinuities in soil strata, and degree and orientation of subsurface stratification and bedding.

Hydrologic and hydraulic properties and other relevant information needed to evaluate the groundwater flow system. These variables are hydraulic conductivity, hydraulic gradient (vertical direction and rate of flow), aquifer type/identification of aquifer boundaries, specific yield (effective porosity)/storage coefficient, depth to ground water, identify uppermost aquifer, identify recharge and discharge areas, use of aquifer, and aquitard type and location.

The technique used to withdraw a groundwater sample from a well should be selected based on a consideration of the parameters which will be analyzed from the

sample. To ensure that the groundwater sample is the representative of the formation, it is important to avoid physical altering or chemical contaminating the sample during the withdrawal process.

4.2.Public Aspects of Monitoring

Monitoring of polluted leachates is an activity necessary for meeting the demands for both fresh groundwater and surface water and for various utilization of aquifer. The suitability of water for human consumption is particularly important. In urban areas, people dig the wells to use groundwater without any treatment process. Therefore, groundwater must be in good quality for the consumption and monitoring activity. In some areas, groundwater has been the only source of water for millions of people.

CHAPTER V

GROUNDWATER QUALITY INVESTIGATION IN TORBALI REGION

5.1. Description of Torbalı Region

Torbali is one of the industrialized urban areas in İzmir. Torbalı village has 600 km² surface area. The region has rich groundwater resources, so groundwater is widely used for industrial, agricultural, and drinking purposes. In Torbalı Region, there are many industries such as automotive, dye, cigarette, oil, textile etc. There is a surface water called as Fetrek Creek but it is dry in summer. The bed of the creek was used for wastewater discharge point by industries for years. In the area, there is no an appropriate sewage collection system and solid waste disposal site.

5.1.1. Meteorological Conditions of the Region

Climate is an important factor affecting the potential for contaminant migration from a release source. Mean values for precipitation, evaporation, evapotranspiration, and estimated percolation help to determine the potential for contaminant transport. In the region, average amount of annual rainfall is 756.6 mm, and the average annual temperature is 17°C. The amount of average rainfall in February/2002, March 2002, and April/2002 are 55.2 mm, 95.8 mm, and 58 mm respectively in Torbalı region.

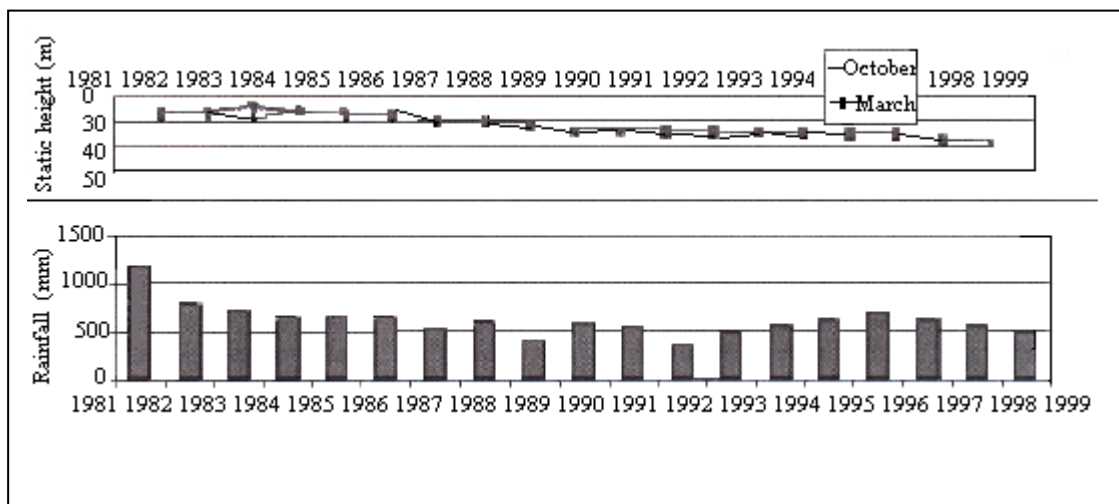


Figure 5.1. The average amount of rainfall between 1981-1999 (Şimşek and Filiz, 2001)

5.1.2. Geological Formation of the Region:

Local bedrock types and depths are important for the investigation of a site. In the region, the alluvium unit which constitutes Torbalı plain is a kind of unconfined aquifer. The main geologic framework is constituted by mezosoic aged marble and silts. The aquifers of the region are formed by neogene aged units and limestone (Şimşek and Filiz, 2001).

5.1.3. Hydrogeology of the Region

In the region, amount of rainfall affects the groundwater level. The regional groundwater flow is from north to south direction. Torbalı Plain recharge from ground and underground karst sources. The water level in the area varies between 20-140 m. The Fetrek Creek is surface water source for the region. It is dry in summer time.

5.1.4. Agricultural Activities in Torbalı Region

In Torbalı region, vegetables (such as pepper, celery, lettuce, leek, etc.), fruits (such as peach, fig, etc), and grains are grown. In the agricultural areas pesticides and manure are used to protect and to fertilize the plants. In the region, ammonium sulfate, CAN (calcium, ammonium, nitrate), ammonium nitrate, triple super phosphate, diammonium phosphate, potassium nitrate, potassium sulfate manures are used in the agricultural activities.

5.1.5. Industrial Activities in Torbalı Region

Torbalı is very close to İzmir Harbor and Aydın Highway. Therefore, the number of industrial applications is increasing. In Torbalı region, olive oil, automotive, textile, marble, leather, and brick industries are located. All the industries need good quality water. Therefore, the industries should prevent to groundwater resources.

5.1.6. Sources of Contaminants in Torbalı Region

In the study area, the industrial activities are growing, so the population of the Torbalı is increasing. Moreover, water demand increases and water usage and water depletion increases. There are many industries in the region. Nearly, all the industries have discharged their wastewaters to the river bed until April 2002.

The waste disposal site of the region which is near a farm has not been designed properly, so contaminants may have been infiltrating to the groundwater.

Table 5. 1.Possible sources of the environmental contaminants in the region

Application	Contaminants
Sewage	Ammonia, nitrate, carbon
Industrial Activities	
Automotive	Al, Cd, Cr, Cu, Fe, Hg, Ni, Pb, Zn
Dye	Suspended solids, cyanide, Cd, Cr, Fe, Pb, Zn
Textile	Oil-grease, phenol, chlorine, sulfur, sulfite, Cr, ammonia
Olive Oil	Oil-grease
Food	Chloride, sodium
Cigarette	Nitrate
Agricultural Activities	Ammonia, nitrate, nitrite, pesticides

5.2.Selection of the Observation Wells

The following criteria were considered in the selection of the observation wells in the region:

- Distribution of the well locations
- Geological framework of the region
- Some of the wells were chosen nearby the industries and Fetrek Creek (Figure 5.2)

According to these criteria, ten sampling points were decided (Figure 5.2). Particularly, wells were chosen near the Fetrek Creek. Because many industries are located near the creek, so some of the observation wells selected from the industries. The wells are W-02, W-05 are in the industries which are very close the Fetrek Creek. Other wells, W-01 and W-06 are from farms which are also near the Fetrek Creek. The others are in the center of Torbalı, at gas stations. These are W-03, W-04, W-07, W-08. Well W-09 is a municipal water source for Torbalı. Sample S-01 is from Fetrek Creek, which was the discharge point of the industries in the region.

5.2.1 Properties of the wells

Wells are located in the areas of industries, farms and gas stations. Pumps were stated in the wells. The depth of the wells are given in Table 5.2 and the location of each well is given in Table 5.3.

Table 5. 2. The depth of the wells

Well No	Depth (m)
W-01	80
W-02	70
W-03	70
W-04	35
W-05	55
W-06	45
W-07	70
W-08	16
W-09	60

Table 5. 3.Purpose of usage and the locations of the sampling points

Sample Number	Location of the wells	Purpose of use
W-01	A farm near the Fetrek Creek	Irrigation
W-02	A textile industry near the Fetrek Creek	Drinking
W-03	A gas station at the center of the city	Drinking
W-04	A gas station at the center of the city	Drinking
W-05	A food industry near the creek	Irrigation
W-06	A farm near the creek	Irrigation
W-07	A gas station at the center of the city	Drinking
W-08	A gas station at the center of the city	Drinking
W-09	One of the municipal water resource at the center of the city	Drinking
S-01	Fetrek Creek (surface water)	-

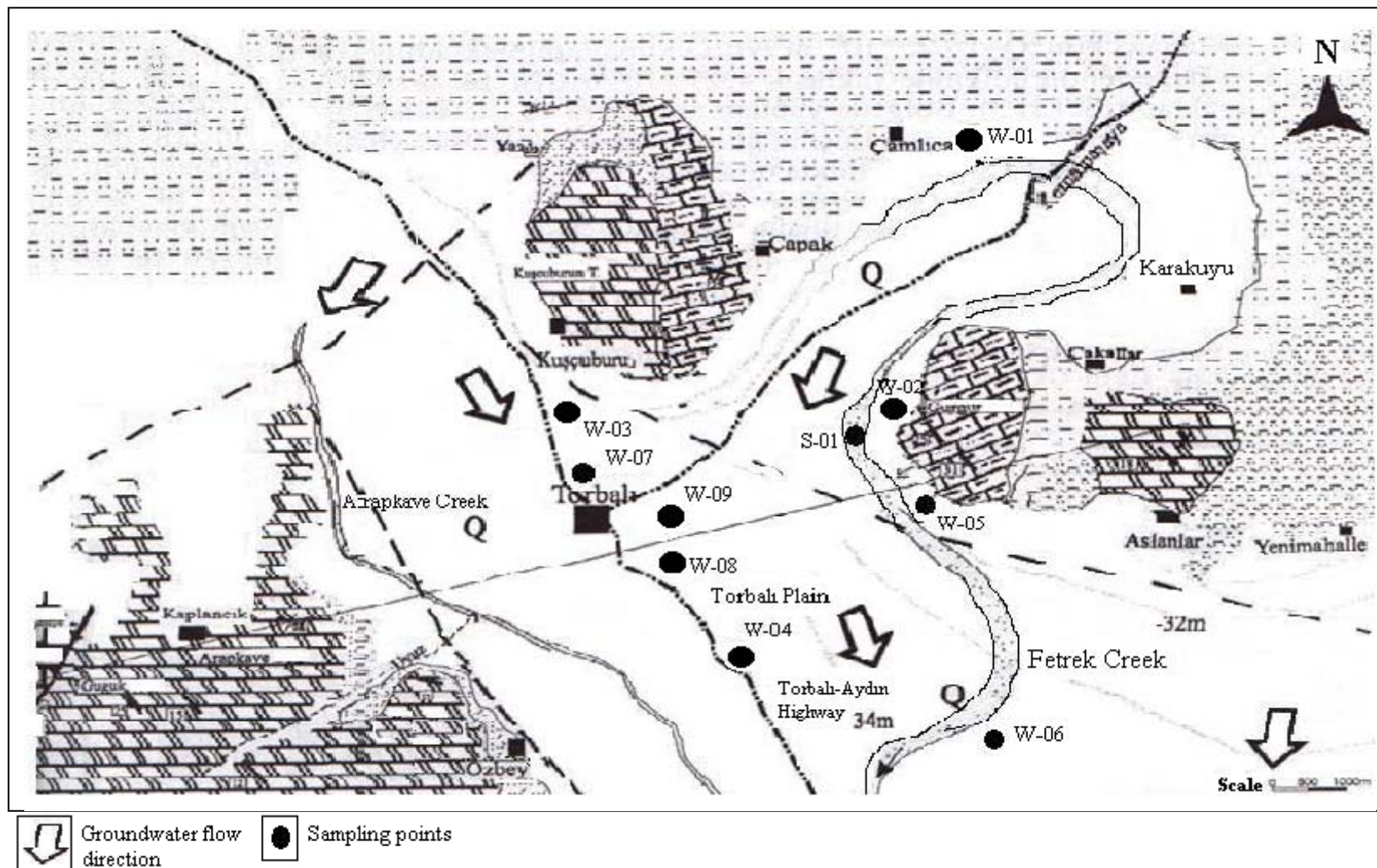


Figure 5.2. Torbalı region and sampling points.

Figure 5.3. Industries are located near the Fetrek Creek

Figure 5.4. A view from Fetrek Creek

5.3. Materials And Methods

5.3.1. Sampling Program

The procedure for collecting a groundwater sample involves the following steps:

- Well evacuation.
- Sample withdrawal.
- In-situ or field analyses and
- Sample preservation and handling.

Preserving samples retards biodegradation reactions, hydrolysis reactions, precipitation reactions and sorption reactions. Sample preservation was applied by adding an acid or base as preservative to adjust pH. Samples were stored at 4°C in the refrigerator. Preservatives were added to the container immediately after collecting the samples. Samples were labeled to avoid misidentification. The groundwater samples were collected using 1 L polyethylene bottles.

Sample containers may require special cleaning before use. For collecting metal samples, nitrate, nitrite, ammonia, chloride, bicarbonate, the sample containers thoroughly were washed with HNO₃ (1+5) solution, then rinsed with deionized water. While collecting samples for chemical oxygen demand, the sample containers were washed with H₂SO₄ solution, then rinsed with deionized water. Each sample container was rinsed with groundwater sample during the sampling study. Each well was evacuated for 5-10 minutes to prevent contamination during sampling through the pipes. The water standing in the well prior to sampling may not be representative of in-situ groundwater quality. Therefore, the standing water was removed in the well so that water which was representative of the formation.

5.3.2. Experimental

5.3.2.1. Determination of Nitrate

Cadmium reduction method was used for nitrate determination. Samples were stored at 4°C, if the samples were analyzed within 24 hours. pH of the samples was adjusted to 2 with sulfuric acid for the storage periods up to 14 days, and samples were stored in cool environment. Before the analysis, samples were warmed to room temperature. When necessary, samples were neutralized with 5.0 N NaOH solution. Spectrophotometer reagents (Nitratever5 Nitrate reagent powder pillows) were used for

the analysis. The reagents included cadmium, gentisic acid, magnesium sulfate, potassium sulfate, and sulfanilic acid. In this method, cadmium metal reduces nitrates present in the sample to nitrite. The nitrite ion reacts in an acidic medium with sulfanilic acid to form an intermediate diazonium salt. This salt couples with gentisic acid to form an amber-colored product. The color development is influenced by the shaking time of the samples. The shaking time must be at least one minute. The color was read by spectrophotometer (HACH DR/2010) in 500 nm wavelength. Nitrate nitrogen standard solution was prepared to check accuracy.

5.3.2.2.Determination of Ammonia Nitrogen

Samples were analyzed for ammonia determination as soon as possible after the collection. The salicylate method was used for the determination of ammonia. The spectrophotometer reagents (Ammonia Nitrogen Reagent Set) were used for the analysis. The reagents included sodium tartrate, sodium citrate, sodium salicate, sodium nitroferrocyanide, lithium hydroxide, anhydrous, and sodium dichloroisocyanurate. In this method, monochloramine reacts with salicylate to form 5-aminosalicylate. The 5-aminosalicylate is oxidised in the presence of a sodium nitroprusside catalyst to form a blue-coloured compound. The blue color is masked by the yellow color from the excess reagent present to give a final green-colored solution. One of the operating conditions is to read the color by spectrophotometer (HACH DR/2010) in 655 nm wavelength.

5.3.2.3.Determination of Alkalinity

Determination of alkalinity is based on a titration of water sample with a strong mineral acid, used as an indicator. The samples were analyzed right after the collection. 0.02 N H₂SO₄ solution was used as titrant. Methyl orange and phenolphthalein solutions were used as indicators. Firstly, phenolphthalein indicator solution was added to the samples. The color of the sample did not change with the addition of phenolphthalein. Then methyl orange indicator solution was added to the samples. Methyl orange indicator gave yellow color to the samples. Titration was applied until red color was seen. The volume of the sulfuric acid which is used during the titration was recorded. Bicarbonate concentration of the samples were calculated by using equation 5.1. The volume of the sulfuric acid was used to calculate calcium carbonate (CaCO₃) concentrations by using equation 5.2. The results of calcium carbonates show the hardness of the sample. The limits of hardness in water is given in Table 5.4.

$$\text{mg/L HCO}_3^- = T \times 24.4 \quad (5.1)$$

$$\text{mg/L CaCO}_3 = T \times 20 \quad (5.2)$$

where; T = volume of sulfuric acid used (mL)

Table 5.4. Classification of waters according to hardness (Uslu and Türkman, 1987)

mg/L CaCO ₃	Hardness
50	Very Soft
50-110	Soft
110-180	Slightly Soft
180-270	Moderately Hard
270-450	Hard
>450	Very Hard

5.3.2.4. Determination of Chloride

Argentometric method was used for the determination of chloride. This method based on the titration of sample with silver nitrate. The samples were analyzed within a week after collection. Potassium chromate (K₂CrO₄) was used as indicator. Hydrogen peroxide (30 %) was used to prevent interference. 0.0141 N AgNO₃ was used as titrant. As the concentration of chloride ion approaches extinction, the silver ion concentration increases to a level of which the solubility product of silver chromate is exceeded and it begins to form a reddish-brown precipitate.

The volume of AgNO₃ solution was recorded and the concentration of chloride was calculated by equation 5.3.

$$\text{mg Cl/L} = \frac{(A-B) \times N \times 35450}{\text{mL sample}} \quad (5.3)$$

where; A= mL titrant for sample

B= mL titrant for blank

N= Normality of AgNO₃

5.3.2.5.Determination of Cyanide

Pyridine-pyrazalone method was used for the determination of cyanide. The samples were analyzed immediately after the collection. Spectrophotometer reagent set was used for the method. These reagents included potassium phosphate, sodium phosphate, 3-methyl-1-phenyl, 2-pyrazolin-5-one, sodium sulfate, ascorbic acid, and pyridine-3-nitrophthalic acid. Reagents were added to the samples and waited half an hour. The samples were read at the appropriate operating conditions such as 612 nm wavelength, room temperature etc. by spectrophotometer (HACH-DR/2010).

5.3.2.6.Determination of Nitrite

The samples were analyzed for nitrite determination right after the collection of the samples. Ferrous sulfate method was used for the determination of nitrite. Spectrophotometer reagent was used for the analysis. The reagent included ferrous ethylenediammonium sulfate, and potassium pyrosulfate. In the method, ferrous sulfate was used as an acidic medium to reduce nitrite to nitrite oxide. Ferrous ions combine with the nitrous oxide to form a dark green complex in direct proportion to the nitrite present.

585 nm wavelength was used to determine the concentration of nitrite by using spectrophotometer (HACH-DR/2010).

5.3.2.7.Determination of Chemical Oxygen Demand

For the determination of the chemical oxygen demand, the samples were preserved with sulfuric acid. The chemical oxygen demand was determined by using colorimetric method. High range COD reagents which include silver and mercury ions were used. Silver was used as a catalyst, and mercury was used to complex chloride interferences. Organic compounds react, reducing the dichromate ion to green chromic ion. In this method, the samples were heated at 150°C for two hours with strong oxidizing agent potassium dichromate. After the samples were heated and cooled, the spectrophotometer (HACH-DR/2010) was used under an appropriate operating conditions (620 nm wavelength). In the method, amount of Cr^{3+} produced was determined.

5.2.8.Determination of Major Cations and Heavy Metals

Ca, Mg, K, Na, Cd, Cu, Cr, Pb, Zn were determined by using inductively coupled plasma atomic emission spectrometry (Varian, ICP-AES). The samples were acidified with HNO₃ to adjust pH less than 2. The samples, prepared by this way, were stored at 4°C for six months. Quantitative method was used. If necessary, samples were filtered. Samples were prepared with HNO₃ (1 mL per 100 mL sample). Multielement standard solution (1000 ppm) which contains 23 elements was used. Standard solutions and blank were prepared by this way. For the determination of Ca, Mg, K, Na, samples were diluted. The operating condition of the analysis are given in Table 5.5. Many wavelengths were experimented to determine the elements. Appropriate wavelength was chosen for each element. Spike recovery was used to control the method. Spike recovery results were appropriate.

Table 5.5.Wavelengths for the determination of the elements by using ICP-AES

Parameter	Wavelength (nm)
Calcium, Ca	315.887
Magnesium, Mg	279.079
Sodium, Na	588.995
Potassium, K	766.490
Cadmium, Cd	228.802
Chromium, Cr	205.552
Copper, Cu	324.754
Lead, Pb	220.353
Zinc, Zn	213.856

5.3.2.9.Determination of Fecal and Total Coliforms

Fecal and total coliforms were analyzed for well W-09 which is one of the municipal water resources in the area. Sample was analyzed within two hours after collection. Sample was collected with an appropriate collection technique to analyze microorganisms. MFC-Broth which includes tryptose, polypeptone, yeast extract,

sodium chloride, lactose, bile-salt, and anilin blue is used to analyze fecal coliforms. Sample was inoculated into the MFC-Broth and it was hold in a incubator at 44°C for 48 hours. M-F Endo Broth which includes M-Endo broth and ethyl alcohol is used to analyze total coliforms. Sample was inoculated into the M-F Endo Broth and was hold in incubator at 37.5°C for 48 hours. There was no microbial growth at well W-09 in January-2002.

For the validation of the accuracy of the applied methods, some of the parameters were also analyzed using either a different preparation method or a different detection method.

CHAPTER VI

RESULTS AND DISCUSSION

Samples which were chosen to represent groundwater quality in the region analyzed from October-2001 to July-2002. The results of the analyses of the study are given in Table 6.1-Table 6.14 and shown in Figure 6.1-Figure 6.13.

pH and EC values were generally constant during the monitoring period for all the samples. According to TS 266, pH values must be between 6.5-8.5. The pH values of the samples were within the limits. The wells W-01 and W-06 are used for irrigation in agricultural activities, therefore the results of the wells were compared to the irrigation water standards. The changes in EC values resulted from increasing ion concentrations, especially increasing of bicarbonate and chloride concentration .

At well W-01, the pH and EC values were between 7.15-7.60 and 720-775 $\mu\text{S/cm}$, respectively. Calcium concentrations were about 100 mg/L in the well W-01. Magnesium and sodium concentrations were about 30.0 mg/L and 15 mg/. Potassium concentrations were about 1.5 mg/L. HCO_3^- and Cl^- concentrations were about 250.0 mg/L and 35.0 mg/L. CaCO_3 concentration was about 210.0 mg/L, and hence, the samples of the well W-01 were characterized as hard water. Well W-01 is used for irrigation in agricultural activities. Concentrations of the parameters in well W-01 were within the limits of irrigation water standards.

At well W-02, pH values were between the permissible limits and the electrical conductivity values were between 1400-1775 $\mu\text{S/cm}$. Calcium concentration was about 155.0 mg/L which exceeded the permissible limit by TS 266. Magnesium concentrations were about 50.0 mg/L which is the limit according to TS 266. Sodium concentrations were about 70.0 mg/L which were within the limits of Turkish Standards. Potassium, HCO_3^- and Cl^- concentrations were about 2.0 mg/L, 250 mg/L and 330 mg/L respectively. HCO_3^- and Cl^- concentrations suddenly changed during the study. CaCO_3 concentrations were about 200.0 mg/L, and hence, the well W-02 was characterized as hard water. Nitrate concentrations were under the limit of TS 266.

At well W-03, pH and EC values were between 7.20-7.70 and 620-850 $\mu\text{S/cm}$, respectively. Calcium concentration was not constant. The lowest calcium concentration was 75.0 mg/L and the maximum calcium concentration was 110.0 mg/L. which

exceeded the permissible limit by TS 266. Magnesium concentrations were about 27.0 mg/L which was also not constant during the monitoring period. Sodium concentrations were about 70.0 mg/L which were within the limits of Turkish Standards. Potassium concentrations were about 1.5 mg/L in autumn-2001 and winter-2002. But the concentration of potassium decreased in summer-2002. HCO_3^- concentrations were not constant during the study. CaCO_3 concentrations showed that the samples of the well could be characterized as hard water. Cl^- concentrations were about 40 mg/L. But the concentration of chloride increased or decreased suddenly. Nitrate concentration was exceed the permissible limit in October-2001 but the concentrations of nitrate were under the permissible limit until July-2002.

At well W-04, pH and EC values were between 7.40-7.50 and 680-710 $\mu\text{S}/\text{cm}$, respectively. Calcium, magnesium, potassium, sodium concentrations are given in Table 6.1. HCO_3^- concentrations were not constant during the study period. The sample of the well W-04 was characterized as hard water. Cl^- concentrations were about 40 mg/L which were within the permissible limits. The concentrations of nitrate were under the permissible limit from April-2002 to July-2002.

The pH and EC values were between 7.10-7.77 and 805-1125 $\mu\text{S}/\text{cm}$ respectively, at well W-05. Calcium concentration was 194.0 mg/L in November-2001 which exceeded the permissible limit. But the concentration of calcium suddenly decreased to 50.0 mg/L in December-2001 and calcium concentrations were not constant during the study. Magnesium concentrations were about 20.0 mg/L. But the concentration of magnesium decreased from 57.0 mg/L to 12.0 mg/L in December-2002. Sodium concentrations were not constant in the well. Sodium concentration of well W-05 was 265.0 mg/L which exceeded the limits of Turkish Standards in November-2001. But it decreased to 70.0 mg/L in April-2002. Potassium concentrations were not constant. The maximum potassium concentration was 5.0 mg/L in December-2001 and the minimum potassium concentration was 3.0 mg/L in July-2002. HCO_3^- concentrations were not constant during the study. The maximum HCO_3^- concentration was 450.0 mg/L in November-2001 and the minimum HCO_3^- concentration was 202.0 mg/L in May-2002. According to CaCO_3 concentrations, the samples of the well W-05 were very hard water in autumn-2001 and hard water in winter-2002 and summer-2002. Cl^- concentration was 247.0 mg/L in December-2001 but it decreased in other months. The concentrations of nitrate were under the permissible limit to July-2002.

The pH and EC values of well W-06 are given in Table 6.2 and Table 6.3 respectively. Calcium concentrations were not constant, because earth crust usually has major cations in high concentrations and the concentrations of the major cations in groundwater samples change with the irrigation activities and/or rainfall. Magnesium concentrations were about 35.0 mg/L. Sodium concentrations were about 23.0 mg/L. HCO_3^- and Cl^- concentrations were not constant, but they were about 300.0 mg/L and 80.0 mg/L, respectively. The concentrations of the parameters were within the permissible limits of irrigation water standards. According to CaCO_3 concentrations, the samples of the well W-06 were classified as hard water.

At well W-07, the pH and EC values were between 7.15-7.60 and 835-895 $\mu\text{S}/\text{cm}$ respectively. Calcium concentrations were about 120 mg/L which were above the permissible limits. Magnesium and sodium concentrations were about 35.0 mg/L and 15.0 mg/L, respectively. Potassium concentrations were about 1.0 mg/L. HCO_3^- concentrations were not constant during the study. The minimum bicarbonate concentration was 293.0 mg/L and the maximum bicarbonate concentration was 358.0 mg/L in December-2001. According to CaCO_3 concentrations, the samples of the well W-07 were hard water. The concentrations of nitrate exceeded the permissible limit. The maximum nitrate concentration was 65.0 mg/L in February-2002 and the minimum nitrate concentration was 30 mg/L in October-2001.

At well W-08, the pH and EC values were between 7.30-7.50 and 726-870 $\mu\text{S}/\text{cm}$ respectively. Calcium concentrations were about 110 mg/L which exceeded the permissible limits. Magnesium concentrations were about 30.0 mg/L. Sodium concentrations were about 20.0 mg/L which was within the limits of Turkish Standards. HCO_3^- concentrations were not constant during the study. CaCO_3 concentrations show that the samples of the well W-08 were hard water. Cl^- concentrations were about 40.0 mg/L which was within the permissible limits. The concentrations of nitrate exceeded the permissible limit in March-2002 and July-2002. The maximum nitrate concentration was 48.0 mg/L in March-2002.

At well W-09, the pH and EC values were between 7.30-7.50 and 680-755 $\mu\text{S}/\text{cm}$ respectively. Calcium, magnesium, sodium, potassium concentrations of the sample were within the permissible limits. HCO_3^- concentrations were not constant during the study period. According to CaCO_3 concentrations, the samples of the well

W-09 were hard water. Cl^- concentrations were about 35.0 mg/L which were within the permissible limits. The concentrations of nitrate were under the permissible limit.

In sample S-01, that is from Fetrek Creek, all parameters were not constant. Every month, values of each parameter were different from previous month. Because this creek was dry and industrial wastewaters were discharged to the Fetrek Creek. They discharge their waste waters to the Fetrek Creek until April/2002.

In rainy seasons, concentration of the all parameters decreased because of the dilution with rain. The amount of rainfall was high in autumn-2001, winter-2002, and April-2002.

Chloride concentration of the samples were constant for all samples except wells W-02, W-05, W-06. The chloride concentration of well W-05 decreases, and the chloride concentration of well W-06 increases with time. The permissible limit for chloride is 250 mg/L. All samples did not exceed the limit except well W-02 in which the chloride concentration changed every month of the monitoring period.

Bicarbonate concentrations of the samples change gradually in all samples. This means that HCO_3^- concentrations of all samples increased or decreased in the same month because of the rainfall. In groundwater samples bicarbonate alkalinity is only exist. During the analysis of alkalinity, the color of the samples did not change with the addition of the phenolphthalein, so the samples had only bicarbonate alkalinity, there was no carbonate and hydroxide alkalinity.

According to the TS 266, the permissible limit for nitrate is 45 mg/L. NO_3^- concentrations of the samples were under the permissible limit except wells W-07 and W-08. Nitrate concentrations of all the samples decreased from October-2001 to April 2002. In rainy seasons, agricultural activities were not applied, which means there was no source for nitrate contamination and the rain caused dilution, so nitrate concentrations of the samples decreased. The results of the nitrate analysis showed that nitrate concentration increased in summer in the region. This result is the proof of the agricultural contamination. Because manure which includes nitrate compounds was applied in summer in agricultural activities. Irrigation caused to leakage of nitrate. Hardness of the all samples increased in summer like nitrate, the reason for the increasing is the infiltration of manure to groundwater.

The concentration of $\text{NH}_3\text{-N}$ mustn't exceed 0.02 mg/L. According to the TS 266 nitrite concentration must be less than 0.05 mg/L. Nitrite nitrogen and ammonia nitrogen concentrations of the samples were higher than the limits, it can be explained

by the leachate of sewage to groundwater. Nitrite and ammonia detection method were not very sensitive, therefore the nitrite and ammonia concentrations were determined approximately.

Fecal and total coliform microorganisms were analyzed at well W-09 which is one of the resources for municipal water usage. The microorganisms were not found in the well W-09 in January-2002.

At well W-02 sodium ion concentration suddenly increased in January-2002. The well is in a textile factory near the Fetrek Creek. The high values of sodium can be explained by the leakage from the Fetrek Creek. Chloride and sodium ion concentrations changed at the same times. The situation can be explained by the leakage of NaCl.

According to TS 266 calcium ion concentration mustn't exceed 100 mg/L. Calcium ion concentrations exceed the permissible limit at wells W-01, W-02, W-03, W-06, W-07, W-08, W-09. Calcium cation concentrations of the samples were constant during the monitoring period except in well W-05. In well W-05 calcium concentration suddenly decreased from 194 mg/L to 49.40 mg/L in December-2001 and did not stay stable. At well W-05, HCO_3^- concentration changed like calcium. It shows groundwater of the well W-05 interact with calcite which is permeable rock, so contamination can reach the groundwater.

At well W-05, sodium ion concentration were more than 175 mg/L which is a permissible limit according to TS 266 in November-2001. But the concentration of sodium decreased gradually every month until July-2002. W-05 is in a food industry near the Fetrek Creek. Tomato is dried and tinned in the factory. The sudden changes can be explained by the leakage of NaCl from factory storage land or from the Fetrek Creek. Chloride and sodium ion concentrations changed in the same months. This shows the infiltration of NaCl into the groundwater. Tomato is dried in summer and NaCl is used in the drying applications over the boundaries of the factory. NaCl can infiltrate to the groundwater by irrigation. The results showed that NaCl infiltrated to groundwater in Summer-2001 and Autumn-2001.

The permissible limit for magnesium ion is 50 mg/L. At well W-02 magnesium ion concentrations were more than the permissible limit.

Potassium is less soluble in water compared to other cations. The concentrations of potassium were under the permissible limit.

Cyanide concentrations of the samples ranged between 0-0.005 mg/L. Cyanide concentrations of the samples were not constant during the monitoring study. It can be explained by the leachate of wastewaters from the Fetrek Creek.

Chemical oxygen demand (COD) concentration of the samples decreased in the rainy seasons (Table 6.14). COD analysis applied until February/2002 because of the technical difficulties. COD concentrations of the wells W-02 and W-05 were higher than 10 mg/L in October-2001 and February-2002. In the wells, concentrations of the other parameters were high in October-2001. It can be explained by the leakage from the Fetrek Creek.

Well W-04 which is in a gas station was in 16 m depth, and it was dry in August-2002. The situation is one of the proofs of groundwater depletion in Torbalı region. In Torbalı region, static water height decrease about 1 m every year (Şimşek and Filiz, 2001).

All samples were analyzed to investigate heavy metals. Inductively coupled plasma-atomic emission spectrometry is used to detect Cd, Cr, Cu, Pb, Zn. During the studying period, heavy metals could not be detected except well W-05 in November-2001. Zinc concentration of well W-05 was nearly 7 mg/L which is higher than the permissible limit. But the concentration of zinc decreased in other months. Lead concentration of the well W-05 was 0.02 mg/L in November-2001. The permissible lead concentration is 0.01 mg/L. Lead concentration decreased in other months like zinc. The other parameters of well W-05 were also high in November-2001 and they decreased in other months. All of the parameters of the well W-05 were not constant during the monitoring study. The situation be explained by sudden discharge of wastewaters into the Fetrek Creek and the discharged wastewater infiltrated into the well W-05. Because the well W-05 is so close to the Fetrek Creek.

Table 6. 1. Temperature values of the samples from October-2001 to April-2002 (°C)

Sample No	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	18	17	16	19	20	19	18
W-02	18	16	13	18	18	20	18
W-03	16	16	12	17	19	20	22
W-04	-*	-*	-*	22	21	24	25
W-05	14	15	14	15	15	16	18
W-06	-*	19	21	20	20	21	20
W-07	15	18	17	19	20	21	21
W-08	-*	15	16	19	20	24	21
W-09	14	17	19	18	18	18	19
S-01	12	10	11	22	25	28	27

*Samples could not be collected from the wells

Table 6.2.pH values of the samples

Sample No	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	7.20	7.22	7.58	7.18	7.43	7.18	7.45	7.40
W-02	7.23	7.10	7.22	7.21	7.55	7.24	7.42	7.43
W-03	7.35	7.50	7.49	7.52	7.61	7.57	7.69	7.20
W-04	-	-	-	-	7.47	7.45	7.49	7.40
W-05	7.35	7.64	7.48	7.56	7.49	7.76	7.68	7.10
W-06	-	7.07	7.30	7.21	7.40	7.42	7.25	7.46
W-07	7.19	7.31	7.29	7.16	7.40	7.42	7.30	7.60
W-08	-	-	7.30	7.40	7.40	7.39	7.37	7.50
W-09	7.47	7.52	7.30	7.37	7.51	7.33	7.48	7.16
S-01	8.00	8.30	8.33	8.30	8.46	8.50	8.46	8.45

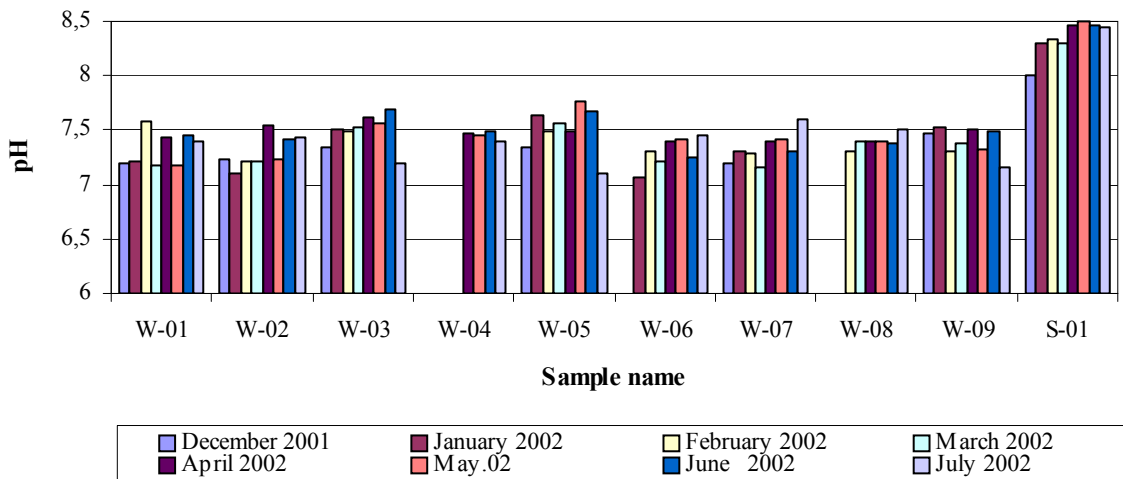


Figure 6.1. The changes of pH values in each well from December-2001 to July-2002

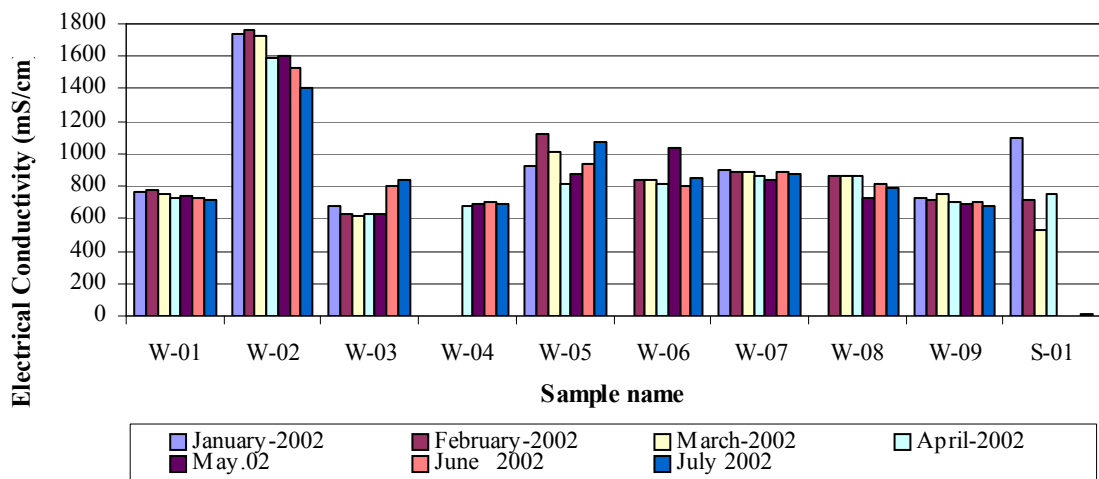


Figure 6.2. Electrical conductivity values from December-2001 to July-2002

Table 6.3. Electrical Conductivity values of the samples ($\mu\text{S}/\text{cm}$)

Sample No	January-2002	February-2002	March-2002	April-2002	May 2002	June 2002	July 2002
W-01	766	771	754	726	735	730	721
W-02	1742	1765	1725	1586	1608	1531	1401
W-03	680	627	622	624	632	799	835
W-04	-	-	-	684	685	707	690
W-05	920	1124	1013	808	879	935	1070
W-06	-	840	838	815	1039	806	856
W-07	895	892	883	859	835	884	871
W-08	-	867	863	857	726	819	783
W-09	725	713	754	702	696	705	682
S-01	1100	715	527	758	2.84	5.43	7.22

Table 6.4. Bicarbonate concentrations of the samples (mg/L HCO₃⁻)

Sample No	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	268.40	311.10	214.72	217.60	274.50	251.3	252.54	292.8	292.8
W-02	244.00	268.40	211.06	219.60	274.50	253.8	248.9	292.8	280.6
W-03	219.60	256.20	186.66	189.10	244.00	219.6	213.0	292.8	305.0
W-04	-	-	-	-	-	246.4	229.4	287.9	280.6
W-05	451.40	423.34	209.84	224.48	250.10	219.6	202.0	256.2	268.4
W-06	-	-	-	268.40	305.00	268.4	292.8	309.9	317.2
W-07	292.80	357.46	256.20	292.80	323.30	292.8	335.5	336.7	341.6
W-08	-	-	-	256.20	329.40	292.8	341.0	317.2	285.5
W-09	292.80	284.26	229.36	280.60	292.80	256.2	311.0	268.4	219.6
S-01	292.80	189.10	219.60	213.50	228.14	170.8	262.8	341.6	341.6

Table 6.5. The results of the chloride ion analysis of the samples (mg/L)

Sample No	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	32.5	38.0	41.0	38.0	35.0	37.0	45.0	37.0
W-02	315.9	355.0	352.5	340.0	307.0	339.0	325.0	270.0
W-03	51.0	41.5	32.5	40.0	30.0	45.0	65.0	53.0
W-04	-	-	-	-	32.0	47.5	45.0	32.0
W-05	246.9	104.5	152.5	140.0	78.5	130.0	120.0	155.0
W-06	-	-	65.0	77.5	105.5	135.0	80.0	90.0
W-07	48.5	54.0	47.5	50.0	42.0	57.5	52.5	57.0
W-08	-	-	40.0	52.5	44.5	57.5	35.0	47.0
W-09	39.0	36.0	50.0	37.5	32.0	47.5	37.0	35.0
S-01	33.5	150.0	60.0	32.5	62.0	640	240	450

Table 6.6. Calcium concentrations of the samples

Sample No	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	109	103	103	104	103	99	100	101	100
W-02	164	150	173	164	158	-	158	160	142
W-03	104	92	93	102	82	75	87	109	106
W-04	-	-	-	-	-	90	92	94	92
W-05	194	49	39	72	68	61	76	79	83
W-06	-	-	-	-	100	118	127	101	105
W-07	129	108	125	114	115	115	111	115	119
W-08	-	-	-	-	108	114	115	106	106
W-09	101	94	100	93	94	96	97	95	93
S-01	43	42	78	106	71	-	86	141	66

Table 6.7. The magnesium concentrations of the samples

Sample No	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	32	30	31	26	30	28	29	28	34
W-02	54	31	61	48	52	-	53	54	50
W-03	32	32	30	19	26	25	25	34	36
W-04	-	-	-	-	-	28	28	30	30
W-05	57	12	11	19	20	18	22	23	25
W-06	-	-	-	-	33	38	41	33	38
W-07	40	21	39	30	35	35	34	35	39
W-08				-	35	36	35	32	34
W-09	25	15	29	27	27	27	28	28	30
S-01	12	5	26	25	19	-	37	56	69

Table 6.8.The sodium concentrations of the samples

Sample No	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	15	19	16	15	18	15	14	15	14
W-02	43	39	75	75	77	-	80	63	61
W-03	12	22	18	14	13	16	14	13	12
W-04	-	-	-	-	-	14	16	14	12
W-05	265	150	104	95	88	68	70	77	84
W-06	-	-	-	-	22	25	26	23	25
W-07	19	11	15	18	19	20	22	18	19
W-08	-	-	-	-	18	19	23	18	15
W-09	14	9	14	16	16	14	17	13	14
S-01	16	28	86	20	17	-	363	522	-

Table 6.9. The potassium concentrations of the samples between November-2001 and July-2002

Sample No	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	2.0	2.0	2.0	2.0	2.0	2.0	1.5	1.0	1.5
W-02	2.0	2.5	2.5	2.0	1.5	-	2.0	2.0	2.0
W-03	1.5	1.5	1.5	2.0	1.0	0.5	0.5	1.0	0.5
W-04	-	-	-	-	-	1.0	1.0	0.5	1.0
W-05	5.0	5	3.0	3.5	4.0	3.5	5	3.0	3.0
W-06	-	-	-	-	-	1.0	1.0	1.0	1.0
W-07	1.5	1.5	1.5	1.5	1.5	1.0	1.0	1.0	1.0
W-08	-	-	-	-	1.5	1.5	1.0	1.0	1.0
W-09	1.5	1.5	1.5	1.0	1.0	2.0	1.0	0.5	0,5
S-01	4.5	2.0	5.5	2.0	1.5	-	5.0	6.5	11.5

Table 6.10.NO₃-N concentrations of the samples (mg/L)

Sample No	October 2001	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	11	5	7	9	9	7	4.5	2	7	5
W-02	6	2	2	2	2	1.5	2	4	5	4
W-03	13	7	8	7	6	4	3	3	8	8
W-04	-	-	-	-	-	-	6	5	9	6
W-05	4	3	3	3	2.5	1	1	1	2.5	2
W-06	-	-	-	-	6	4.5	3	2.5	3	3.5
W-07	7	11	12	10	15	12	8.5	8	9	11
W-08	-	-	-	-	8	11	7	7.5	9	7.5
W-09	5	6	6	6.5	14	7	5	6	8	
S-01	9	3	2	3	4	2	1	1.5	7	

Table 6.11. Concentration of NO₃⁻ from October-2001 to April-2002 (mg/L)

Sample No	October 2001	November 2001	December 2001	January 2002	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	48.0	23.5	29.0	40.0	40.7	32.0	19.8	10.75	26.0	28.4
W-02	24.5	6.2	9.8	8.3	8.6	6.0	8.7	17.5	18.1	17.0
W-03	58.0	31.3	34.5	30	27.6	18.1	13.2	15.0	32.0	34.4
W-04	-	-	-	-	-	-	24.0	24.0	34.6	30.8
W-05	18.0	12.1	12.1	14.5	11.7	2.0	5.0	3.8	7.6	8.1
W-06	-	-	-	24.1	29.6	19.0	12.4	13.8	11.3	16.1
W-07	30.0	48.5	53.5	46.0	64.6	52.2	37.0	35.5	36.3	48.3
W-08	-	-	-	-	36.6	48.0	32.0	34.0	37.1	45.0
W-09	22.5	26.0	28.1	29.7	62.0	30.3	20.7	26.0	33.0	33.1
S-01	36.5	12.0	9.3	14.5	18.5	8.0	5.2	7.6	27.0	30.0

Table 6.12. Concentration of NO₂-N from October-2001 to February-2002 (mg/L)

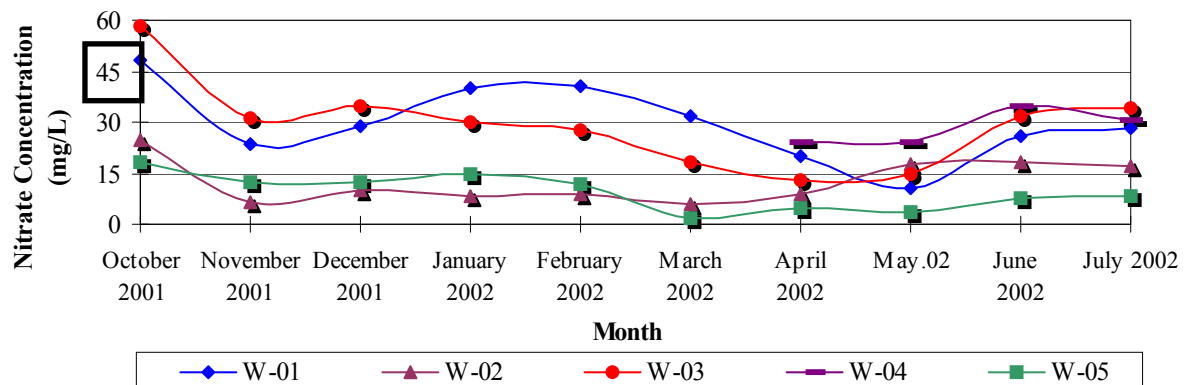
Sample No	October 2001	November 2001	December 2001	January 2002	February 2002
W-01	2.0	1.0	2.0	1.0	2.0
W-02	1.0	1.0	2.0	3.0	1.0
W-03	2.0	1.0	2.0	1.0	2.0
W-05	1.0	1.0	2.0	1.0	-
W-07	1.0	1.0	1.0	1.0	-
W-08	1.0	1.0	2.0	1.0	1.0
W-09	2.0	1.0	2.0	1.0	2.0
S-01	10.0	9.0	8.0	3.0	5.0

Table 6.13. The results of the NH₃-N analysis (mg/L).

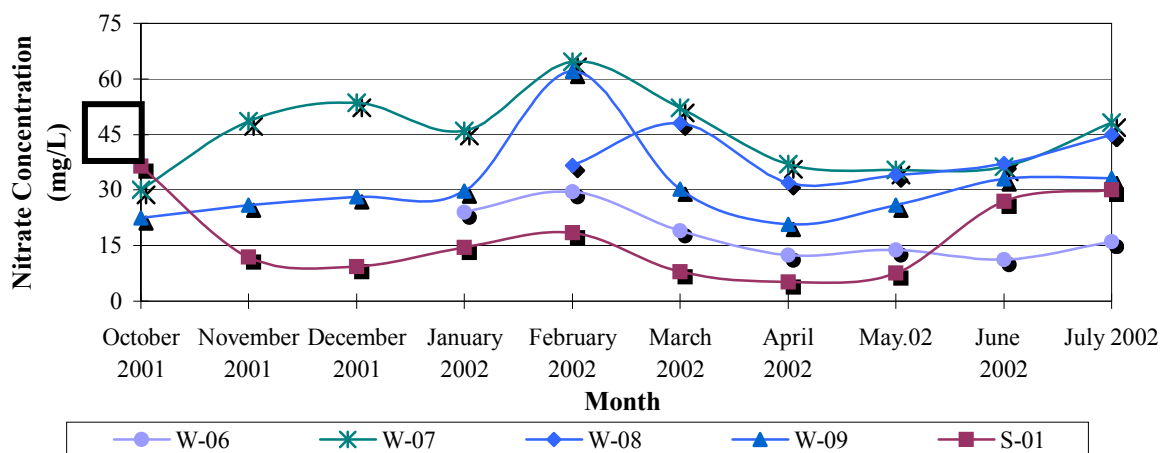
Sample No	November 2001	December 2001	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	0.05	0.02	0	0	0.02	0.01	0.03	0.03
W-02	0.17	0.05	0.04	0.03	0.02	0.02	0.01	0.01
W-03	0.07	0.02	0.06	0	0	0.01	0	0
W-04	-	-	-	-	0.01	0	0.02	0.02
W-05	0.11	0.06	0.05	0.03	0.05	0.01	0.01	0.01
W-06	-	-	0.02	0.03	0	0	0.06	0.05
W-07	0.08	0.05	0.09	0.03	0.01	0.02	0.03	0.03
W-08	-	-	0.08	0.02	0	0.02	0.01	0.02
W-09	0.05	0	0.08	0.03	0.07	0.05	0.02	0.03
S-01	0.16	0.23	0.12	0.06	0.07	0.06	0.06	0.09

Table 6.14. Chemical Oxygen Demand concentrations of the samples (mg/L).

Sample No	October 2001	November 2001	December 2001	January 2002	February 2002
W-01	17	2	0	4	0
W-02	122	3	0	5	56
W-03	44	15	2	1	0
W-05	124	10	4	4	44
W-06	-	-	-	1	85
W-07	2	0	0	4	3
W-08	-	-	7	-	4
W-09	4	1	1	8	1
S-01	482	36	16	30	13



(a)



(b)

Figure 6.3. Nitrate concentrations of the wells; a)W-01, W-02, W-03, W-04, W-05

b) W-06, W-07, W-08, W-09, S-01

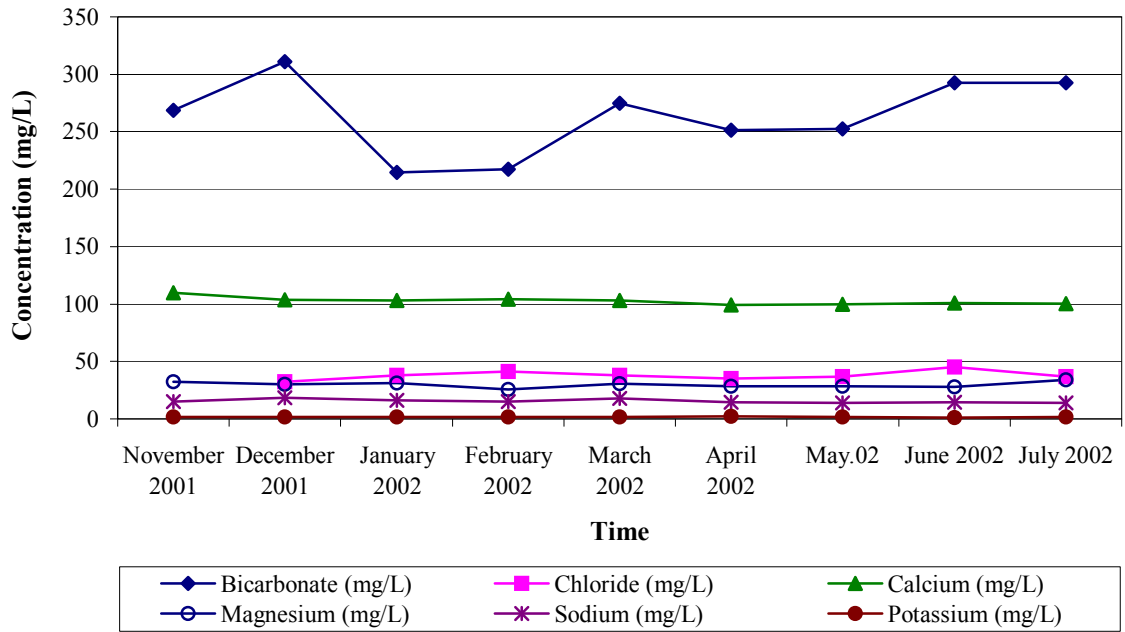


Figure 6.4. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-01 since November-2001 to July-2002.

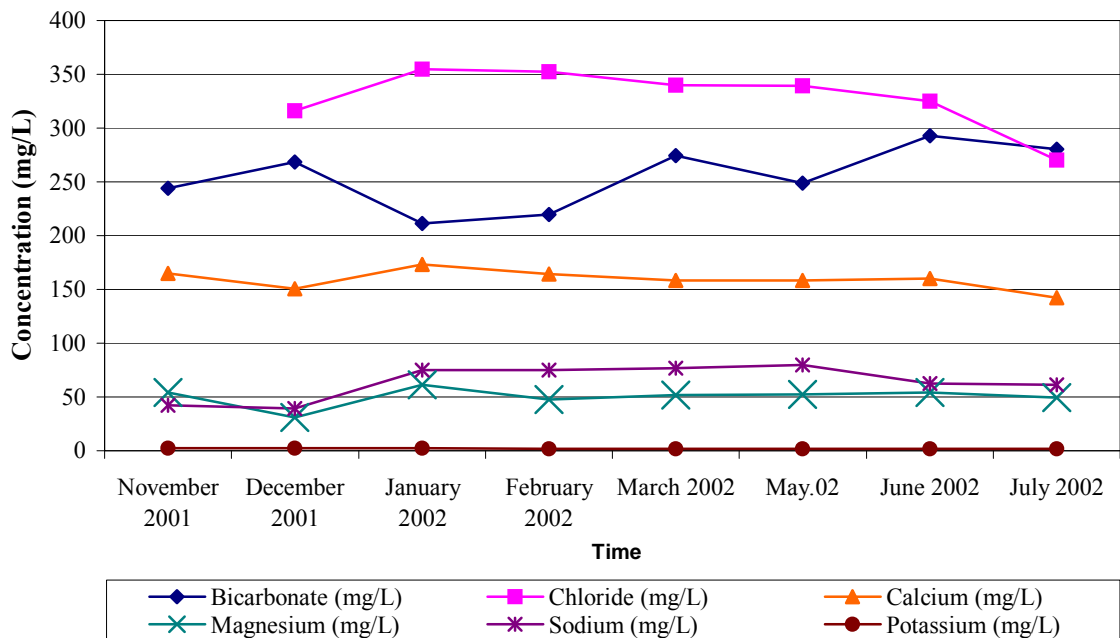


Figure 6.5. Calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-02 since November-2001 to July-2002.

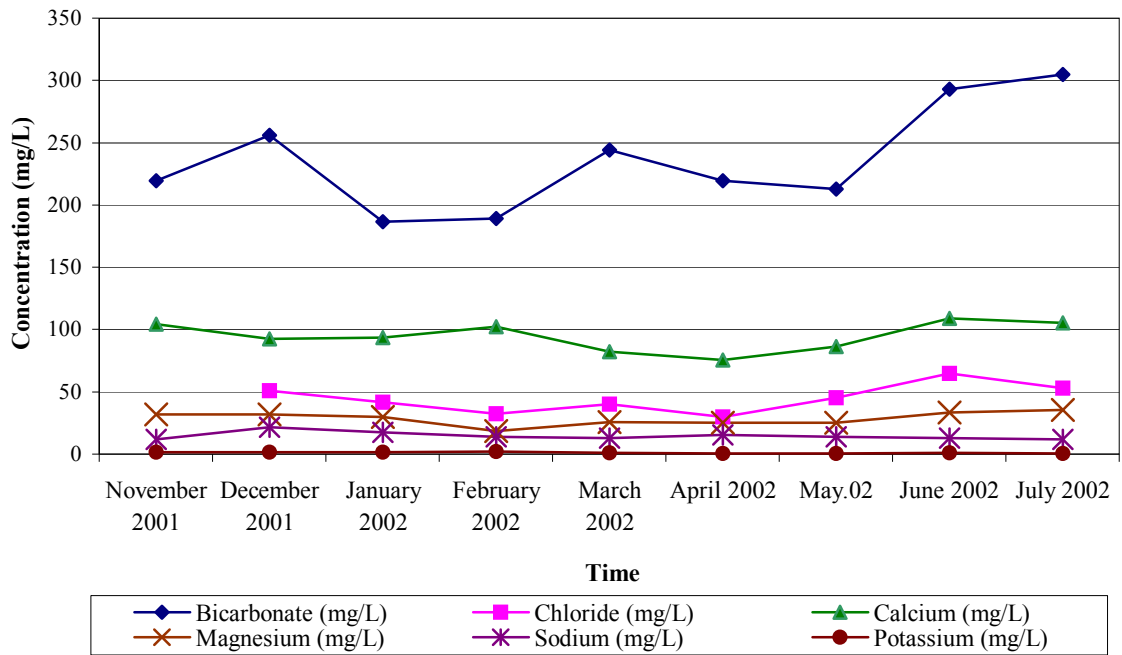


Figure 6.6. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-03 since November-2001 to July-2002.

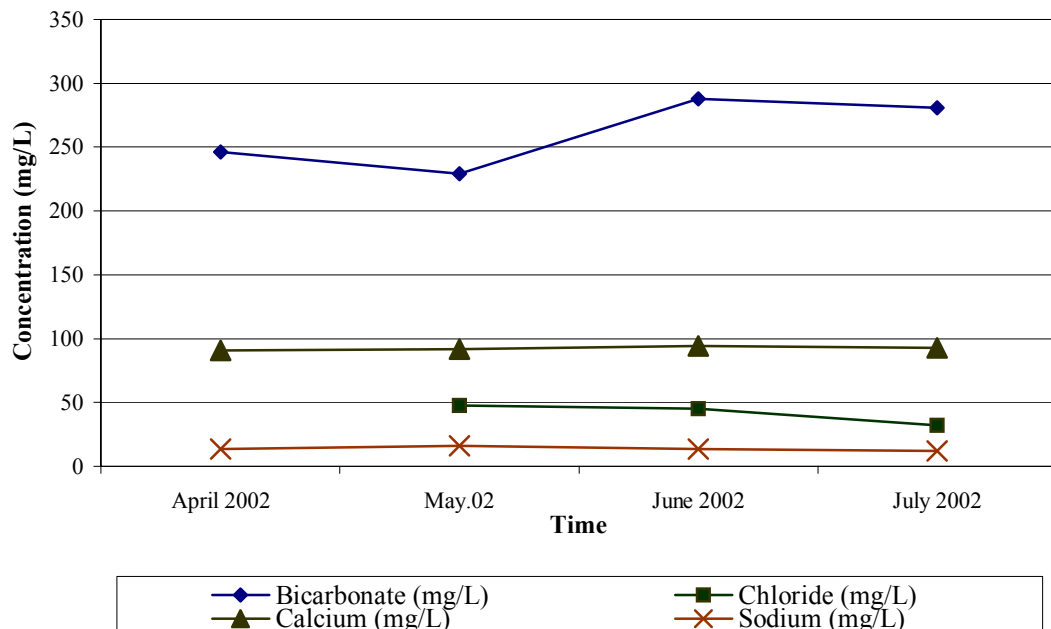


Figure 6.7. The changes of calcium, sodium, bicarbonate, and chloride concentrations in well W-04 since April-2002 to July-2002.

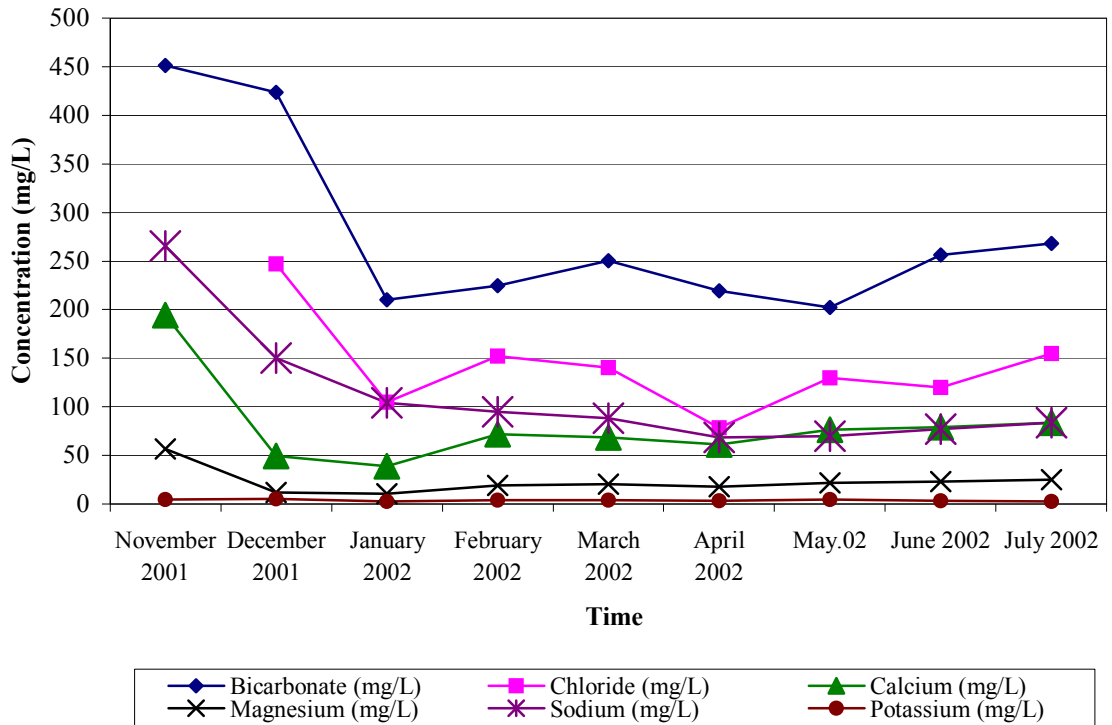


Figure 6.8. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-05 since November-2001 to July-2002.

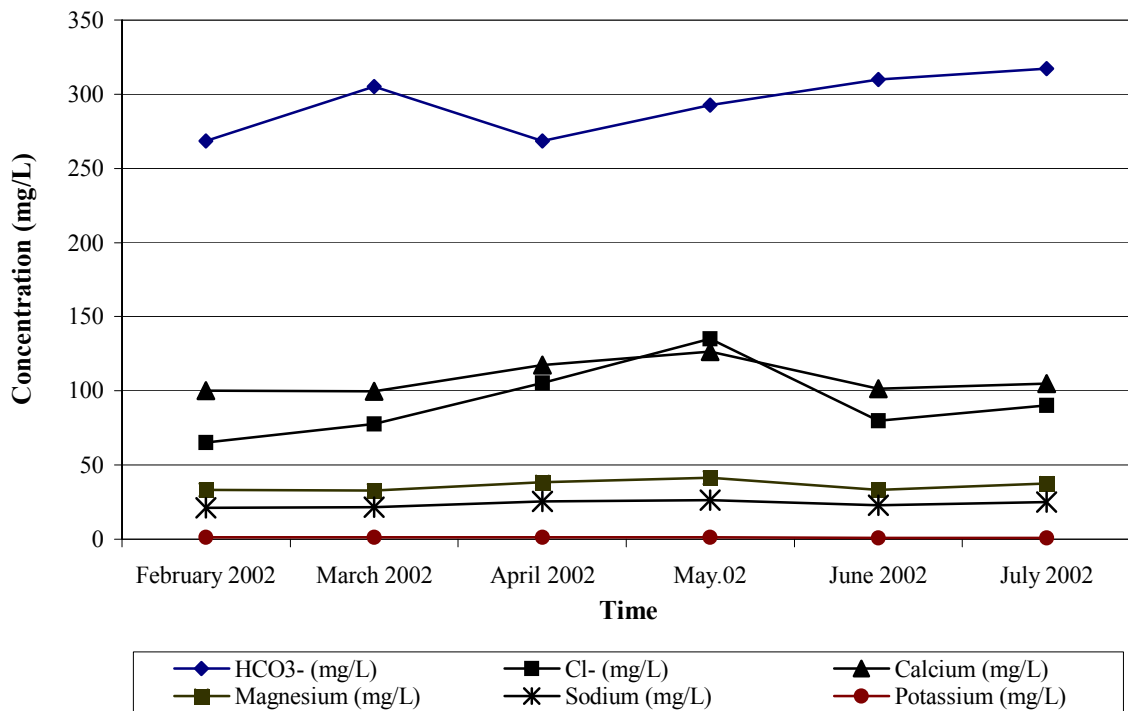


Figure 6.9. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-06 since February-2002 to July-2002.

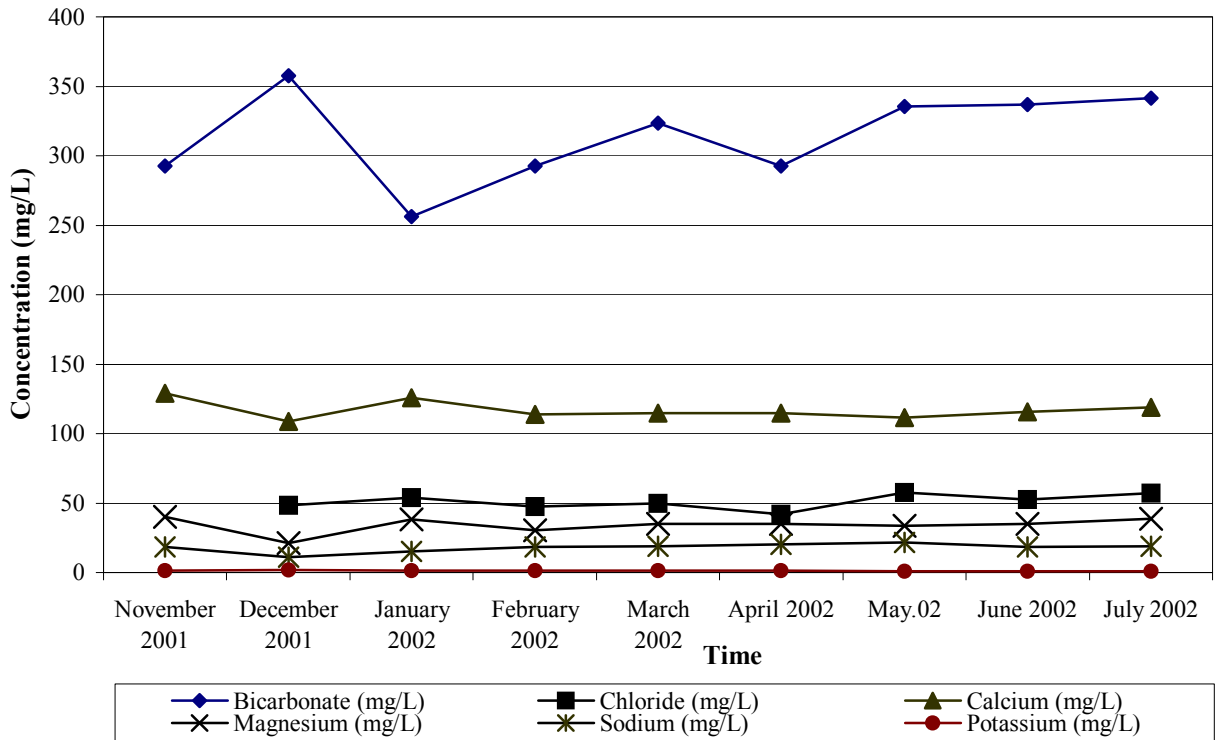


Figure 6.10. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-07 since February-2002 to July-2002.

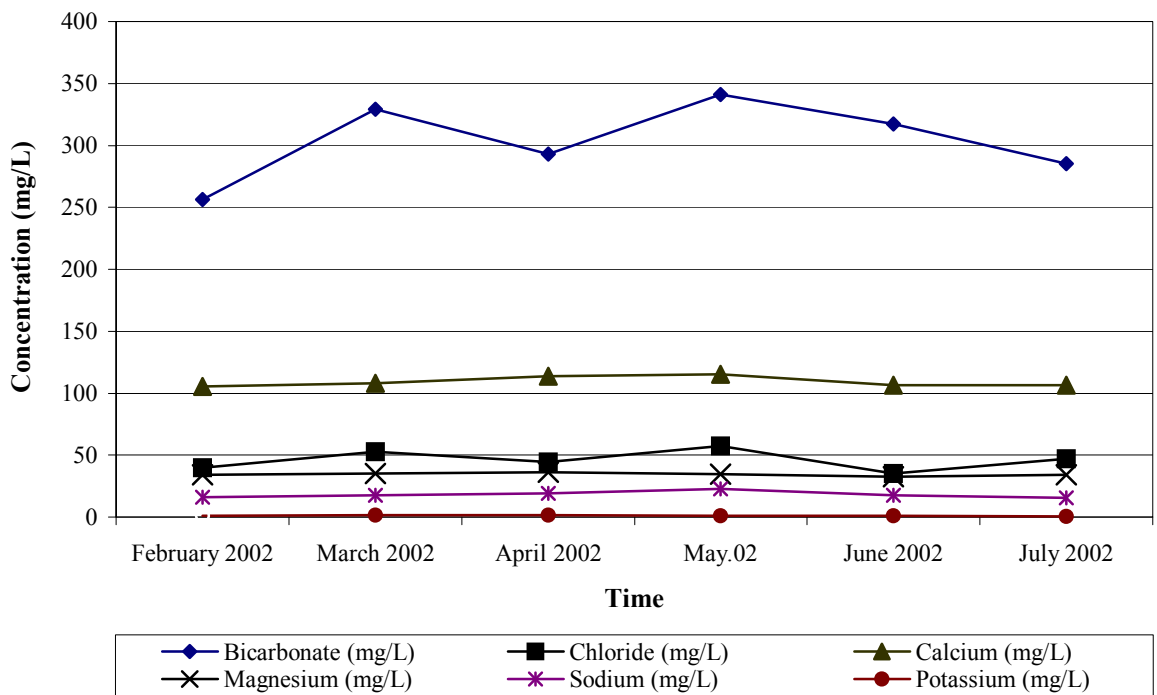


Figure 6.11. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-08 since February-2002 to July-2002.

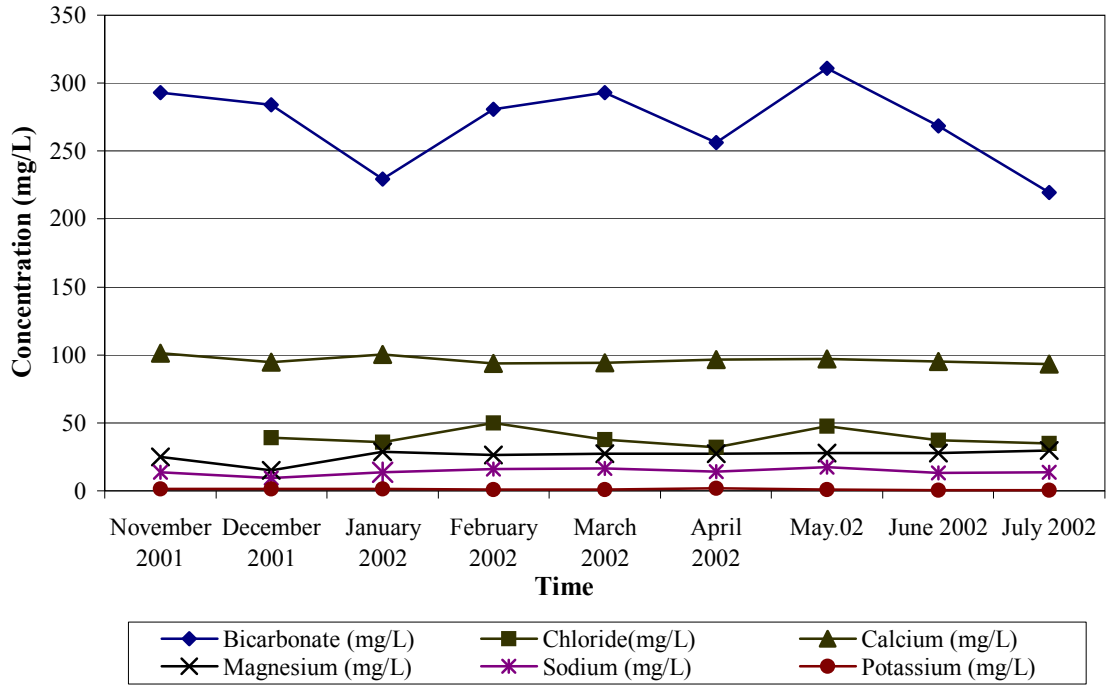


Figure 6.12. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in well W-09 since February-2002 to July-2002.

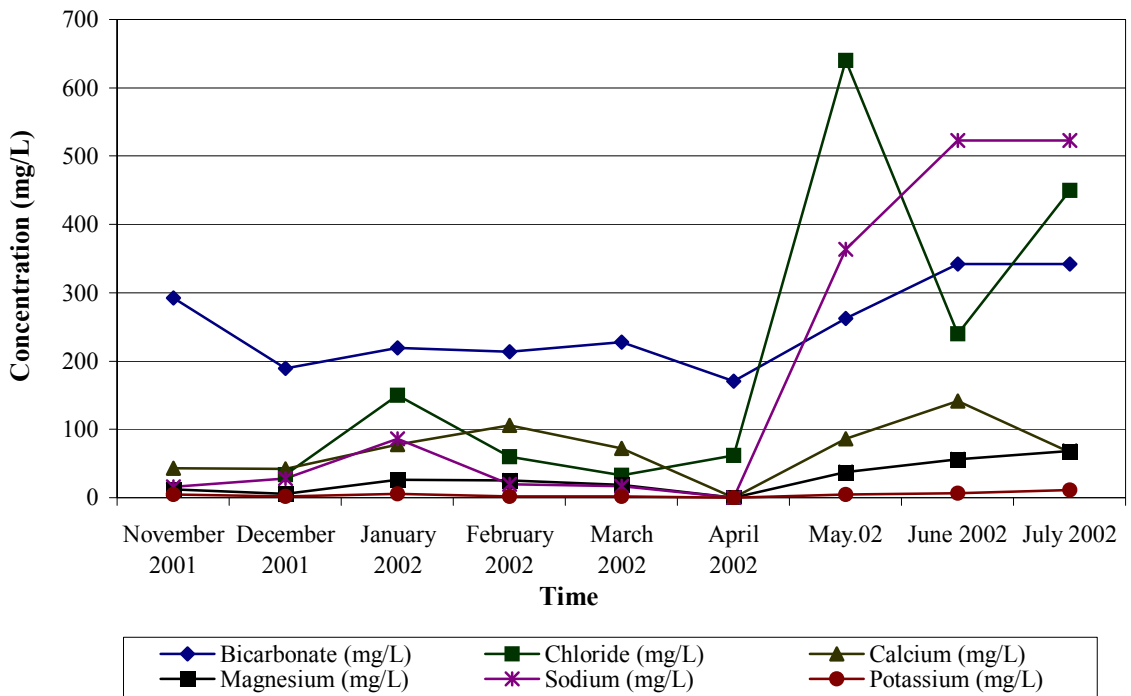


Figure 6.13. The changes of calcium, magnesium, sodium, potassium, bicarbonate, and chloride concentrations in S-01 since February-2002 to July-2002.

Table 6.15.Cyanide concentrations of the samples (mg/L)

Sample Number	November 2001	December 2001	February 2002	March 2002	April 2002	May 2002	June 2002	July 2002
W-01	0.05	0.02	0	0	0.02	0.01	0.03	0.03
W-02	0,17	0,05	0,04	0,03	0,02	0,02	0,01	0,01
W-03	0,07	0,02	0,06	0	0	0,01	0	0
W-04	-	-	-	-	0,01	0	0,02	0,02
W-05	0,11	0,06	0,05	0,03	0,05	0,01	0,01	0,01
W-06	-	-	0,02	0,03	0	0	0,06	0,05
W-07	0,08	0,05	0,09	0,03	0,01	0,02	0,03	0,03
W-08	-	-	0,08	0,02	0	0,02	0,01	0,02
W-09	0,05	0	0,08	0,03	0,07	0,05	0,02	0,03
S-01	0,16	0,23	0,12	0,06	0,07	0,06	0,06	0,09

CHAPTER VII

CONCLUSIONS AND RECOMMENDATIONS

The objective of the study was to investigate the groundwater quality, relationships between the quality parameters and the sources of contamination in Torbalı region.

Samples were collected from 10 different sampling points from October-2001 to July-2002. Samples were collected by using an appropriate collection method for each parameter. pH, temperature, electrical conductivity, calcium, magnesium, potassium, sodium, chloride, alkalinity, nitrate, nitrite, ammonia, copper, chromium, cadmium, lead, zinc, chemical oxygen demand (COD), and cyanide were monitored.

Torbalı is rich in groundwater which is used widely by industries, farmers and public. But, excessive use of groundwater caused the depletion of groundwater.

As a result of interactions between groundwater and the geological materials through which it flows groundwater has bicarbonate alkalinity. Earth crust consist of high concentrations of calcium, so groundwater samples are classified as hard/very hard water. The groundwater samples of Torbalı region also have bicarbonate alkalinity and were also classified as hard water.

Agricultural contamination was determined in the region. Nitrate concentration of the samples increased in summer because of the agricultural activities. Manures which include nitrogen compounds were used in summer in the region, and therefore, irrigation caused to nitrogen leachate. Nitrate is used as a fertilizer to enhance the plant's growing. Therefore, the abuse of nitrate must be controlled. The toxicity of nitrate to humans is due to the body's reaction of nitrate to nitrite. This reaction causes to methemoglobinemia to infants.

Nitrite and ammonia concentrations were found above drinking water standard. In Torbalı region, some groundwater wells are monitored by determining nitrate, ammonia, nitrite, and pathogens by Torbalı Directorate of Health in every month. According to the studies total coliform was detected in some of the wells.

Organic matter contamination was investigated in the study area. Chemical oxygen demand concentrations were higher than the permissible limits in some months during the monitoring period. Industrial wastewaters may infiltrate into groundwater

from the Fetrek Creek. Because of the infiltration of wastewaters into groundwater, COD concentrations increased in some months.

The Fetrek Creek is dry in summer time and the creek bed was used by industries as discharge point of wastewaters. Industries discharged their wastewaters to the Fetrek Creek until April-2002. The discharging of the wastewaters to the creek was prevented by government. The discharge points must be strictly controlled.

Groundwater conservation areas should be ascertained. The owners and the users of the areas should be informed and forced to apply conservation studies. The regulations for watershed management were strictly applied in the areas.

The consumption of manure and chemicals (insecticides, herbicides, etc.) should be limited in agricultural activities. The permissible limits mustn't be exceeded.

Leakage should be prevented. Leakage from solid waste disposal area threatens the groundwater resources. There are agricultural activities and the wells around the solid waste disposal site in Torbalı region.

According to Control of Water Pollution Regulation (SKKY, 1988), wells must be prevented from pollution. Conservation areas of the wells must be hedged and should be strictly controlled to prevent from contamination. Any settlement mustn't be exist around the conservation areas. Infiltration of the chemicals, wastewaters, etc. must be prevented. Solid waste disposal area must be designed to prevent infiltration. According to the regulation, agricultural chemicals must be easily degradable in nature and mustn't accumulate in human body when groundwater is used for drinking.

Information on well construction features, condition of the well, and location of the well relative to water distribution, storage or treatment systems are needed to evaluate the suitability of the well for usage. The information about the wells has not been completed for the whole study area.

Groundwater vulnerability mapping studies can be applied in whole area.

Surface water and groundwater can be used conjunctively. There are many advantages of groundwater storage compared to surface storage, and independent use. Conjunctive use is cheaper than dams and reservoirs operated separately.

Protection of groundwater quantity and quality can be accomplished by controlling potential contaminant sources and by managing land uses in primary recharge areas. Using knowledge of local geology and groundwater flow directions, estimates can be made of the land areas contributing recharge to a particular well or to an aquifer as a whole. Controls can then be established to ensure appropriate land uses

and chemical practices within the recharge areas. The best protection is provided through land acquisition. The agricultural activities and the industrial applications should be controlled over the aquifer.

In the study, microbiological assessment was not applied for all the wells, so microbiological contamination require further studies. Pesticide contamination can also be determined in the region in another study. Sudden discharges should be determined by using advanced monitoring methods. Samples were collected monthly for ten months, in this study. But monitoring studies should be applied to study area for years. Therefore, this study should not be the last study for the region.

REFERENCES

1. AWWA, "Chemical Oxygen Demand, Argentometric Method," In *Standard Methods for the Examination of Water and Wastewater*, (American Public Health Association, Washington, 1995) p(4-49, 5-12)
2. Asarođlu M., Sunlu U., Kaymakçı A., "İzmir'in bazı ilçelerindeki yeraltı su kaynaklarının kalite kriterlerinin incelenmesi," In *İzmir Su Kongresi proceedings*, (İzmir-1999)
3. Bedient P.B., Rifai H.S., Newell C.J., "Groundwater Contamination," In *Groundwater Contamination Transport and Remediation*, (Prentice Hall, New Jersey, 1999) p(70)
4. Belgiorno V., Napoli R.M.A., "Groundwater quality monitoring", Water Science and Technology, Vol.42, 1-2, (2000), 37-41
5. Canter L.W., "Nitrate in Groundwater", In *Nitrates in Groundwater*, (Lewis Pub, New York, 1997) p(75)
6. Dajlido J.R., Best G.A., "Alkalinity," In *Chemistry of Water and Water Pollution*, Ellis Horwood Limited, 1993) p(130)
7. Davis G.H., "What is Groundwater", In *Groundwater and Public Policy*, (Purdue, Pennsylvania, 1991) p(12)
8. Environmental Protection Agency, "Groundwater Investigations", In *Handbook of Ground Water Vol.2 Methodology*, EPA (NewYork-1988) p(114)
9. Eryurt A., Sekin Y., "Manisa Bölgesi yeraltısularında mevsimsel deđişiklikler sertlik ve azotlu maddeler," In *ÇEVJEO'2001 proceedings*, (İzmir-2001)
10. Freeze A.R., Cherry J.A., "Physical Properties and Principles, Chemical Properties and Principles, Groundwater Contamination," In *Groundwater* (Prentice-Hall, 1974)
11. Gökçe O., Kaya F., Atış İ., "Tarımda yeraltısuyu kullanımı ve çevre ilişkileri: İzmir ve Manisa illeri örneđi," In *ÇEVJEO'2001 proceedings*, (İzmir-2001)
12. Gupta M.K., Singin V., Rajwanshi P., Agarwal M., Rai K., Srivastava S., Shrivastav R., Dass S., "Groundwater quality assesment of Tehsil Kheragarh , Agra (India) with special references to fluoride", Environmental Monitoring and Assessment, 59, (1999), 275-285
13. <http://www.epa.gov/safewater/mcl.html>, 19.08.2002
14. <http://www.wmo.Ch/web-en/wdwfea.html>, 27.08.2002

15. Kartal M., Görkmen A., “Türkiye’de yeraltısuyu potansiyeli ve kullanımı,” In ÇEVJEO’2001 proceedings, (İzmir-2001)
16. Kumbur H., Arslan H., Özer Z., “İçel ili içme ve kullanma suyu kaynaklarının kirlilik durumunun araştırılması ve çözüme yönelik modellerin oluşturulması,” In I. Türkiye Su Kongresi proceedings, (İstanbul-2001)
17. Langmiur D., “Humic and Fulvic Acids,” In Aqueous Environmental Geochemistry, (Prentice-Hall, New Jersey, 1997) p(161)
18. Max.H., Charlotte G., “Groundwater Quality,” In Wells and Septic Systems, (New York, 1991)
19. Özçelik Ş., Sarıöz K., “Eskişehir ovası yeraltısuyu kirliliğinde 1995 sonrası olumlu gelişmeler,” In ÇEVJEO’2001 proceedings, (İzmir-2001)
20. Polat M., Yılmaz N., “Antalya havzasında yeraltı su kaynaklarında kirliliğin belirlenmesi ve koruma stratejileri,” In ÇEVJEO’2001 proceedings, (İzmir-2001)
21. Price M., “Water Circulation” , In Introduction to Groundwater, (Chapman and Hall, New York, 1996) p(15)
22. Rao Y.S., Reddy T.V.K., Noyudu P.T., “Groundwater quality in the Niva River Basin, Chittoor district, Andhra Pradesh, India”, *Environmental Geology*, Vol.37, (1997), 56-63
23. Reijnders H.F.R., Dreht van G., Prins H.F., Boumans L.J.M., “The quality of the groundwater in Netherlands,” *Journal of Hydrology*, 207, (1998), 179-188
24. Resmi Gazete, 1997, Sayı 23144 p(34)
25. Resmi Gazete, 1988, Sayı 19919, Su Kirliliği Kontrolü Yönetmeliği
26. Resmi Gazete, 1991, Sayı 20748, Su Kirliliği Kontrolü Yönetmeliği Numune Alma ve Analiz Metotları Tebliği
27. Soltan M.E., “Characterization, and evaluation of some ground water samples in upper Egypt”, *Chemosphere*, Vol.37, 4, (1998), 735-745
28. Şimşek C., Filiz Ş., “Torbalı Havzasının Hidrojeolojik İncelenmesi,” In ÇEVJEO’2001 proceedings, (İzmir-2001)
29. Todd D.K., “Quality of Groundwater,” In Groundwater Hydrology, (John Wiley and Son’s, New York, 1980)
30. Trauth R., Xanthopoulos C., “Non-point pollution of groundwater in urban areas”, *Water Research*, Vol 31, 11, (1997), 2711-2718
31. Trautman M., Porter K.S., Wagenet R.J., “Groundwater,” In Groundwater: What It Is and How to Protect It, (Natural Resources Cornell Cooperative Extension, 1998)

32. Türkman A., “Deneysel Bulguların İrdelenmesi” Doktora Tezi, (İzmir-1981)
33. Umar R., Ahmad., M.S., “Groundwater quality in parts of central Gang Basin, India”, *Environmental Geology*, Vol.39, 6, (2000), 673-678
34. Uslu O., Türkman A., “Sertlik ve Agresiflik,” In *Su Kirliliğine Kontrolü*, (T.C.Başbakanlık, Ankara, 1987) p(86)
35. Waste Management Division Office of Solid Waste U.S.Environmental Protection Agency, “Ground Water,” In *Interim Final RCRA Facility Investigation Guidance Volume II of IV, Soil, Ground Water and Subsurface Gas Releases*, (EPA, New York, 1989)
36. World Health Organization, “Groundwater,” In *Guidelines for Drinking Water Quality Vol.2*, (Prentice-Hall, New Jersey, 1984) p(269)
37. www.env.gov.bc.ca:8000/wat/gws/gwbc/C02_origin.html, 18.02.2001
38. Zoller U., “Groundwater Contamination,” In *Environmental Science and Pollution Control, Groundwater Contamination and Control*, (Marcel Dekker, New Jersey, 1994) p(530)

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