DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

EFFECTS OF WASTEWATER IRRIGATION ON GROUNDWATER QUALITY

by
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İZMİR

EFFECTS OF WASTEWATER IRRIGATION ON GROUNDWATER QUALITY

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M.Sc THESIS EXAMINATION RESULT FORM

We have read the thesis entitled **"EFFECTS OF WASTEWATER IRRIGATION ON GROUNDWATER QUALITY"** completed by **Deniz Ulaş DOĞANLAR** under supervision of **Prof. Dr. Ayşen TÜRKMAN** and we certify that in our opinion it is fully adequate, in scope and in quality, as a thesis for the degree of Master of Science.

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ABSTRACT

Groundwater is an important fresh water source all over the world. It is used for industrial, domestic and agricultural purposes. Because of its lower cost and higher quality (compared with surface water), groundwater is a preferable resource. Although groundwater resources are replenishable; they are not inexhaustible. Water scarcity around the world force people to find alternative sources. One of these alternative sources is irrigation with treated wastewater, but this solution has some negative effects on groundwater quality.

In this study, effects of irrigation with İzmir Municipality Wastewater Treatment Plant effluent water on Menemen Plain groundwater are tried to be determined. Treatment plant's effluent contains about 2,000 mg/L chloride concentration. Aquifer in the plain is determined as vulnerable for pollution. Treatment plant's effluent may cause chloride concentration increase in groundwater. Dilution with Gediz River may be thought as a solution but Gediz River's water is fourth class according to Quality Criteria of Inland Water Resources Classification. On this respect, possible dilution ratios are calculated and results are evaluated.

Keywords: Groundwater, wastewater reuse, irrigation.

ATIKSU İLE SULAMANIN YERALTISUYU KALİTESİ ÜZERİNE ETKİLERİ

ÖZ

Yeraltısuyu, tüm dünyada önemli bir tatlı su kaynağı olup endüstriyel, evsel ve tarımsal amaçlarla kullanılmaktadır. Düşük maliyeti ve yüksek kaliteli (yüzeysel sulara göre) olması nedeniyle tercih edilmektedir. Yeraltısuları, yenilenebilir olmalarına rağmen tükenmez kaynaklar değillerdir. Tüm dünyadaki su kıtlığı, insanları alternatif kaynaklar bulmaya zorlamaktadır. Bu kaynaklardan biri arıtılmış atıksu ile sulama yapmaktır; ancak bu çözümün, yeraltısuyu kalitesine olumsuz etkileri olabilmektedir.

Bu çalışmada, Menemen Ovası'nın İzmir Büyükşehir Belediyesi Evsel Atıksu Arıtma Tesisi çıkış suları ile sulanmasının yeraltısuyu kalitesi üzerine etkileri incelenmeye çalışılmıştır. Arıtma tesisi çıkış suyunun klorür konsantrasyonu yaklaşık 2,000 mg/L'dir. Ovadaki akiferin kirlenmeye duyarlı olduğu tespit edilmiştir. Arıtma tesis çıkış suyu, yeraltısuyunda klorür konsantrasyonunun artmasına sebep olabilir. Arıtma tesisi çıkış suyunun Gediz Nehri suyu ile seyreltilmesi çözüm olarak düşünülebilir; ancak Gediz Nehri'nin suyu, Kıta İçi Su Kaynakları Sınıflandırması'na gore dördüncü sınıf sudur. Bu amaçla, olası seyreltme oranları hesaplanmış ve sonuçlar değerlendirilmiştir.

Anahtar Sözcükler: Yeraltısuyu, atıksu geri kullanımı, sulama.

CONTENTS

CHAPTER ONE
INTRODUCTION

1.1 Water Demand in the World

Total water quantity in the world is 1.4 billion km^3. 97.5 % of this water is in oceans and seas (salty water) and 2.5 % is in rivers and lakes. 90 % of this little sweet water is captured in poles and under ground (Devlet Su İşleri, [DSİ], 2006).

Increasing population, pollution of surface and groundwater, periodic droughts and heterogeneous dispersion of water sources enforce people to find new water sources for the future. While water demand is increasing both in world and in our country, water sources are becoming exhausted and polluted**.**

Demand for water is increasing all over the world in recent years. Many countries will face water insufficiency today or in future (Karataş, 1999).

1.2 Water Demand in Turkey

Average precipitation in Turkey is 501 billion m^3. 69 billion m^3 of this water feeds the groundwater; 274 billion m^3 evaporates from soil, surface waters and plants; 158 billion m^3 flows through the rivers and arrives to the seas or lakes. 28 billion m^3 of groundwater feed returns to the surface water by the springs (DSİ, 2006).

Water resources have continuously rising importance in recent years all over the world. This is emphasized in Middle East Region where Turkey is situated. The region has a semi-arid climate, therefore the water potential is low, and on the other hand, rapidly growing population causes continuous increase in water demand (Türkman, Aslan, & Yılmaz, 2002).

If usable water quantity for a person is less than 2000 m^3 / year in a country; this country is defined as “water poor country” and Turkey is one of these countries. Usable water for a person in one year is nearly 1500 m^3 in Turkey (DSİ, 2006).

1.3 Water Demand in İzmir

İzmir is Turkey’s third largest city and second important port. The city is a busy commercial and industrial center as well as the gateway to the Aegean Region. In this region; dyes, soaps and textiles are manufactured and foods and tobacco are processed. İzmir has typical Mediterranean climate with hot summers and warm wet winters.

İzmir can be considered as a lucky city when the water resources are considered. The groundwater resources in İzmir are rich and meet more then 65% of total amount supplied. İzmir city has faced water deficiency many years ago. The origin of the problem was insufficient water resources and high water losses in network in addition to rising water demands (Türkman, Aslan, & Yılmaz, 2002).

In İzmir, 1197 ha area is irrigated from ponds, 10356 ha is irrigated from surface waters and 10196 ha is irrigated with groundwater (Köy Hizmetleri Genel Müdürlüğü, 2006).

1.4 Purpose and Scope of the Study

Treated wastewater is reused in many places in the world, especially in the regions, which have limited water sources. In İzmir, irrigation water, which is obtained from Gediz River and groundwater, is insufficient. Also people need groundwater for other purposes like obtaining drinking water. Because of these, authorities are thinking to use İzmir Municipal Wastewater Treatment Plant’s effluent as irrigation water, instead of insufficient groundwater, in Menemen Plain.

Using wastewater for irrigation usually causes salt problem in groundwater. An increase in the salt concentration of the groundwater both affects plant kinds of the plain and people who obtain drinking water from groundwater.

In this thesis, İzmir Municipal Wastewater Treatment Plant's effluent quality values and Menemen Plain groundwater quality values are compared according to irrigation water standards. Vulnerability of the plain is tried to be estimated by DRASTIC Index. Chloride concentration is taken into account to follow salt problem. Dilution ratio of treated wastewater by Gediz River is calculated to determine its suitability as irrigation water and to prevent salination of groundwater.

CHAPTER TWO
IMPORTANCE AND POLLUTION OF GROUNDWATER

2.1 Importance of Groundwater

Groundwater is a renewable water resource and it has generally high quality because of the natural filtration, which occurs while water is passing through the soil layers. Groundwater becomes enriched by dissolving the minerals of the rock during the transfer to the lower layers related to temperature, pH, pressure, contact area and contact time. Some trace metals' concentrations may exceed the limit values because of the medium condition (Çekliler, 1999).

2.2 Pollution Problems of Groundwater

The very rapid urban growth of the last few decades causes an increase in water. Because of this growth and industrialization, surface water resources are now fully either exploited or of poor quality and groundwater resources have become increasingly important. Water is an extremely scarce resource in arid and semi-arid regions (Commission of the European Communities Overseas Development Administration [ODA], 1996).

Population is increasing rapidly in recent years in the world and in Turkey. Parallel with this, tourism activities and housing in coastal zones are increasing, too. These factors cause abnormal decrease in groundwater level; and increase in groundwater pollution. This situation can cause to pay too high costs or costs that cannot be compensated (Karataş, Panahi, & Aşık, 1999).

Groundwater is a vital national resource that is used for myriad purposes. It is used for

_ Public and domestic water supply
systems
_ Irrigation and livestock watering
_ Industrial, commercial, mining,
and thermoelectric power production purposes.

In many parts of the USA, groundwater serves as the only reliable source of drinking and irrigation water. Unfortunately, this vital resource is vulnerable to contamination, and groundwater contamination problems are being reported throughout the country (EPA, 2005)

Groundwater is seen as an inexhaustible source because it is refreshable in nature, but in fact it is not inexhaustible. After 1988, for a long time, especially in Middle Anatolian and Aegean Zone through the drought, farmers who have used surface water before, wanted to use groundwater for irrigation. Drought in Aegean Zone caused extreme groundwater level decreases in wells and threaten wide areas by causing increase in the negative effects of geothermal waters (Çekliler, 1999).

Groundwater is generally high-quality water. The reason of this is the natural filtration that occurs as the water passes through the soil layers. The reaching speed of a contaminant to groundwater is related to both soil and contaminant type (Dokuz Eylül University, Environmental Engineering, 1999)

Groundwater quality can be adversely affected or degraded as a result of human activities that introduce contaminants into the environment. It can also be affected by natural processes that result in elevated concentrations of certain constituents in the groundwater (EPA, 2005).

Groundwater flow rate in an aquifer is an important factor for groundwater pollution. A polluted aquifer may stay as polluted for hundreds of years because of too slow flow rate (less than 30 m/year). If an aquifer that is used to obtain drinking water is polluted, to leave the polluted wells and to open new wells far away from these wells or to search alternative surface resources may be needed (Karataş, Panahi, & Aşık, 1999).

CHAPTER THREE
WASTEWATER REUSE FOR IRRIGATION

3.1 Examples from the World

In many arid and semi-arid regions of the world, wastewater is used for irrigation. An important part of present water reuse systems use the treated wastewater that is re-gained for agricultural purposes. 34% of treated wastewater in Florida is used for agricultural irrigation purpose. This ratio is 63% in California. If it is explained in volume; in California, Florida and Texas; in the same order, $570*10^3$ m^3, $340*10^3$ m^3 and $1100*10^3$ m^3 treated wastewater is used for irrigation. In Texas example; treated water is given to two different artificial ponds. Ponds are designed to supply the leakage between each other to control surface water raise. Later, an amount of water is taken from a river that is around the ponds and is given to one of the ponds, so mixture of all water is achieved (DEU, Env. Eng., 1999).

Israel gave an impressive example of saving water resources through the use of wastewater for irrigation (www.iaea.org, 2004). In a study in Israel, it is reported that wastewater reuse has been practiced on a large scale and has reached 60-70% of all municipal wastewater production – one of the highest in the world. In several regions in Israel, salinization of the soil has already been encountered, and there is a permanent increase in water salinity at the coastal aquifers. Reports of many studies indicate a significant salinity increase in the unsaturated zones and at upper interface layers of the groundwater table. Typical salt contribution in terms of kg/capita is shown in Table 3.1. In Israel, the salinity increment in municipal use amounts to 500 g TDS/m^3 (mostly sodium salts) including 150 g chlorides/m^3. The TDS and chloride content of fresh water supply on the average in Israel is relatively high: 700 g/m^3 and 160 g/m^3, respectively (Rebhun, 2003).

Table 3.1 Annual salt contributions in kg/cap/y (Rebhun, 2003).

Source	Chlorides	Total Salinity
Urine	3	9
Other activities commerce and industrial	6	18
Total	9	27

Table 3.2 summarizes the salinities of water supply, the increments, the total salinity of wastewater and mass input of salinity from wastewater in tons per year assuming annual reuse of 300 Mm^3/y of wastewater (Rebhun, 2003).

Table 3.2 Salt content and mass contribution in wastewater (Rebhun, 2003).

	Chlorides	TDS
Water supply, g/m^3	160	700
Increment, g/m^3	160	500
Wastewater, g/m^3	320	1200
Annual mass, t/y for 300 Mm^3/y	100.00	360.00

The 300 Mm^3/y of wastewater effluent carries 360.00 tons of salt annually (100.00 tons of chlorides). The disposal of these effluents to the sea (or via rivers to the sea), as in the case in countries and regions that do not need reclamation for agricultural irrigation, would also purge those hundreds thousands of tons of salt out of the land (from the country). In this case, the use of reclaimed effluents for irrigation without drainage to the sea brings about an accumulation of hundreds of thousands of tons of salt inside the country every year (Rebhun, 2003).

The salinity balance of input of water and salinity is shown in Table 3.3. Fresh water and wastewater outflows to the sea are estimated as 150 Mm^3/y and 50 Mm^3/y, respectively, giving a total salt (TDS) outflow of only 120,000 t/y.

Table 3.3 Annual water and salinity inputs on land in Israel (Rebhun, 2003).

Source	Water Mm^3/y	Chloride, t/y	TDS, t/y
Groundwater	1000	100,000	300,000
Natural Water Sources (NWC)	300	60,000	180,000
Reclaimed wastewater	250	90,000	270,000
Industrial wastewater	50	30,000	100,000
Total	1600	280,000	850,000

Accumulation of salt is 730,000 t/y of TDS (mostly sodium salts) including 230,000 t/y of chlorides. Most of this salinity is loaded on 200,000 hectares of the irrigated part of the land overlying the coastal aquifer and adjacent valleys in a small country (Rebhun, 2003).

The balance shows that the annual salinity loading may reach close to 4 tons per hectare of TDS and 1 ton of chloride every year.

Some parts of this salt remain at least temporarily in the upper soil with recently reported negative effects on crop production. Most of the remaining saline soil solutions penetrate to the subsurface, the unsaturated layer and eventually reach the groundwater.

Effects of salinization are felt on a time scale of ten of years in Israel. However, in several regions, soil salinization has already been encountered and there is a permanent increase in water salinity in the coastal aquifer (Rebhun, 2003).

Most perturbing reports are indicating a very significant salinity increase in the unsaturated zones and in the upper interface layer of the groundwater table. This salt accumulation is a time bomb because it may cause irreversible salinization of the aquifers and endanger the future of main water sources (Rebhun, 2003).

Also, accumulation of specific heavy metals can be seen in soils irrigated with reclaimed wastewater. Though negative effects of heavy metals have not been felt up to now, the rate of accumulation predicts such effects in 10 to 30 years of continuing practices of irrigation. Partial desalinization (using membrane processes) of reclaimed wastewater is needed to reduce the salinity load, to purge salt from the country, and to prevent salinization of land and water to enable sustainable reuse (Rebhun, 2003).

Again in Israel, a general evaluation is given by Haruvy (2000): "One of the problems involved in irrigation with effluent is the danger of acceleration of contamination of groundwater mainly by chlorides, nitrogen and heavy metals. An approach is designed to the economic evaluation of acceleration on the concentration of chlorides on groundwater due to irrigation with effluent. The approach is based on hydrological model predicting the flow of chlorides through the unsaturated zone of the subsoil, into the groundwater below. Time needed for completion of flow of chlorides inputs through the unsaturated zone, is about 5 years close to the seashore of Israel. It takes about 20 years in central part of the Coastal Plain, and tens up to hundreds of years in the southern-east part of the Coastal Plain. A threshold for chloride concentration in the water supply for human consumption was assumed to be 250 ppm (The current requirement of chlorides is 250 ppm in Israel and 100 ppm in Europe; it is assumed that in the future, the required threshold in Israel will be 150 ppm Cl^-). The model assumes that when the concentration of the chlorides in the groundwater reaches the threshold of 250 ppm chloride the value somewhat higher than the threshold, desalination of groundwater should be applied using the reverse osmosis technology."

In another report, from Tunisia, it is said that; water and salt leaching requirements needed to be known more respectively to avoid water losses and more studies on solute transport had to be conducted to prevent groundwater pollution (Bahri, 2000).

In a study about irrigation with wastewater in Punjab, following results are found (www.iaea.org, 2004):

Irrigation dilutes the pre-existing salt concentration and increase again when evaporation turns seepage from vertical down to vertical up.

After irrigation soil shrinking starts, while dew dilutes the salt concentration close to the surface of the profile.

At a groundwater table of 3 to 4 m below ground level irrigation practice in silt sediments does not influence groundwater quality. Therefore, low chloride containing groundwater moves from the groundwater table by capillary forces into the unsaturated zone, diluting and narrowing the Cl^- peak that was broadened in the unsaturated zone by irrigation. On the contrary, in sandy sediments with a water table close to the ground surface (e.g. 2.5 m) salt is imported by irrigation into the groundwater and becomes reimported into the unsaturated zone as far as the seepage changes from downward into an upward direction (www.iaea.org, 2004).

During the rainy season (monsoon) some through-flow in all types of profiles takes place, causing dilution and leaching of salts that accumulated during the dry season in both irrigated and non-irrigated soils. This produced the low chloride concentrations in sandy silts before the irrigation experiment started.

The salinization of sediments in the unsaturated zone is mostly caused by evaporation:

* Salts accumulate permanently in the unsaturated zone if the water table is below 3 m and irrigation is not applied very often; this salt do not reach the water table.
* At least once a year monsoon rains dilute and exports salts.
* Salinization is enhanced if the water table nearly reaches the surface (< 3m)

In the Punjab with missing morphology, i.e. the differences in morphologic altitudes are smaller than the differences in hydraulic heads needed for groundwater flow, there is an additional effect enhancing salinization. To protect the effective root zone and constructions against groundwater, deep drainage channels have been constructed that often do not discharge effectively due to missing topographic gradients. The channels favor evaporation even to deeper than 3 m.

Since the very slow process of water logging cannot be avoided due to the existing infiltration of irrigation water, buried drainages or water pumping was recommended to better manage water logging and soil salinization. Pumped or drainage subsurface waters, however, should not be discharged to irrigation channels from where it reinfiltrated to the underground (www.iaea.org, 2004).

3.2 Standards in Turkey for Wastewater Irrigation

Standards for irrigation water are given in Table 3.4. As it can be seen from the table, if the electrical conductivity of the water is higher than 2000 µS/cm or chloride concentration is higher than 426 mg/l, this water should not be used as irrigation water if it is not obligatory.

Table 3.4 Irrigation water quality parameters in irrigation water classification (Technical Bulletin Methods, 1991)

	Irrigation Water Class				
Quality Parameters	I. Class water (very well)	II. Class water (good)	III. Class water (usable)	IV. Class water (if obligatory, usable)	V.class water (harmful) Not appropriate
$EC_{25}x10^6$	0-250	250-750	750-2000	2000-3000	> 3000
Exchangeable Sodium Percent (% Na)	< 20	20-40	40-60	60-80	> 80
Sodium Adsorption Rate (SAR)	< 10	10-18	18-26	> 26	
Residual Sodium Carbonate (RSC) mg/L	< 66	66-133	> 133		
Chloride (Cl^-), mg/L	0-142	142-249	249-426	426-710	> 710
Sulphate ($SO_4^=$) mg/L	0-192	192-336	336-575	575-960	> 960
Total Salt Concentration (mg/L)	0-175	175-525	525-1400	1400-2100	> 2100
Bor concentration (mg/L)	0-0.5	0.5-1.12	1.12-2.0	> 2.0	-
Irrigation water class*	C_1S_1	C_1S_2,C_2S_2, C_2S_1	C_1S_3,C_2S_3, C_3S_3,C_3S_2, C_3S_1	C_1S_4, C_2S_4, C_3S_4, C_4S_4, C_4S_3, C_4S_2, C_4S_1	-
NO_3^- or NH_4^+ mg/L	0-5	5-10	10-30	30-50	> 50
Fecal coliform ** 1/100 mL	0-2	2-20	20-100	100-1000	> 1000
BOD_5 (mg/L)	0-25	25-50	50-100	100-200	> 200
Suspended Solid (mg/L)	20	30	45	60	> 100
pH	6.5-8.5	6.5-8.5	6.5-8.5	6.5-9	< 6 or > 9
Temperature	30	30	35	40	> 40

* Found from Figure 1

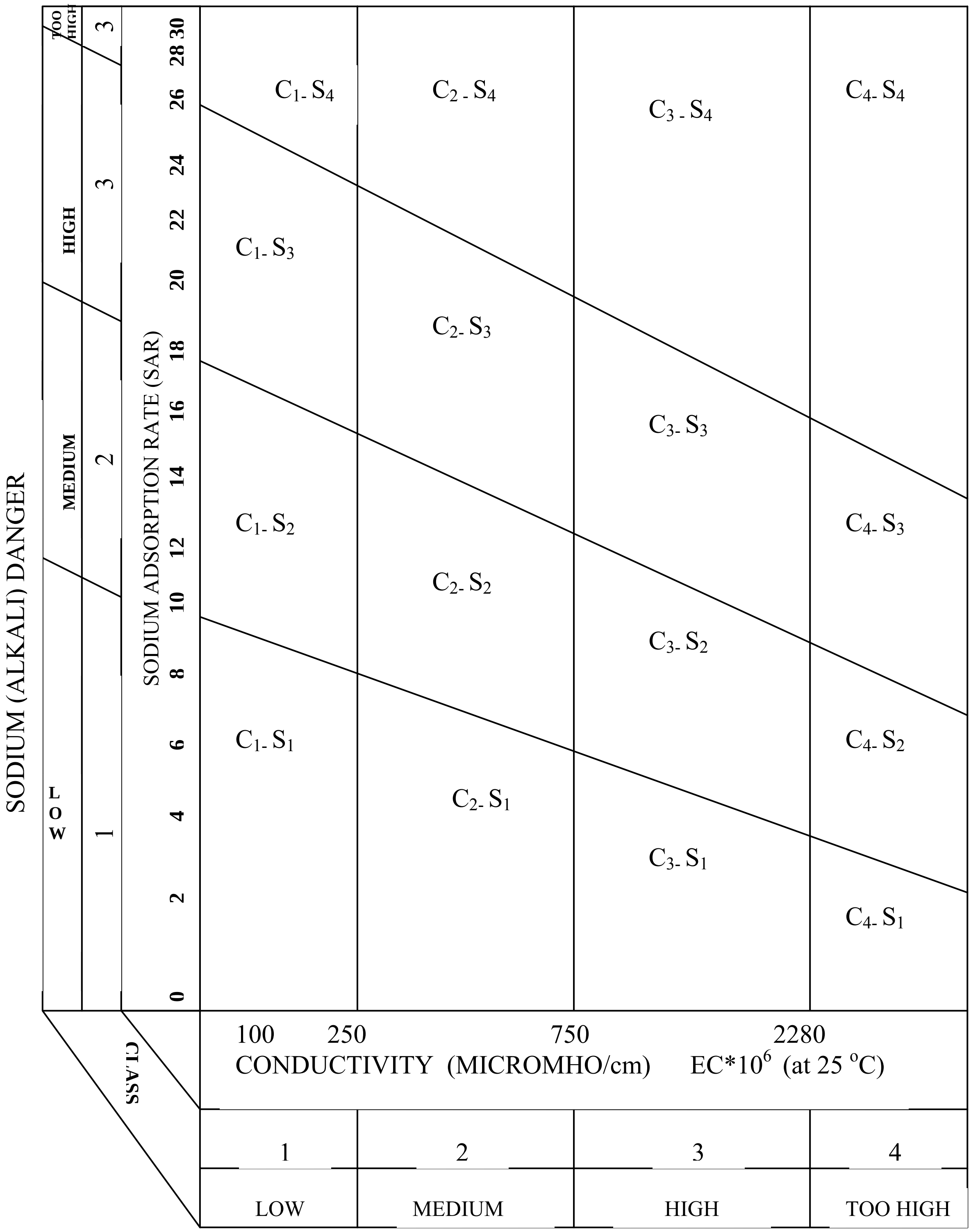


Figure 1: Diagram used in irrigation water classification (Water Pollution Control Act, 1991).

3.3 Effects of Wastewater Irrigation

Although applying treated wastewater has a big advantage of saving water, it has some disadvantages, too. These affects are summarized below.

3.3.1 Effects on Human Health

Past studies show that domestic wastewater usually contains all pathogenic organisms. Cholera epidemic in Jerusalem in 1970, which occurred as a result of eating the vegetables irrigated with sewage water, is accepted as an indicator of this. Pathogenic microorganisms in treated wastewater, which is used for irrigation, are a potential danger for public, especially for farmers and consumers who buy the products which are irrigated with this water (Aşık, Karataş, & Panahi, 2001).

Preventing people from the pathogenic microorganisms that are found in wastewater is the most important point in using wastewater as irrigation water. Following precautions can be taken to achieve this purpose:

- Disinfections of the bacteria and other pathogens which are present in wastewater
- To measure the residual chloride (if the wastewater is chlorined), in addition to fecal coliform measurement
- Irrigation must be applied at nights or at the times which do not cause risks for human health
- Necessary caution signs must be put indicating wastewater reuse

(DEU, Env. Eng., 1999).

3.3.2 Effects on Plants

Quality of irrigation water is related to total dissolved salt concentration and many other parameters. Salts, which will be carried to the area by irrigation water, can decrease the production and cause soil pollution in the long run. All plants do not have the same sensitivity to salt. If the salinity of the soil cannot be controlled, then salt resistant plants must be chosen (DEU, Env. Eng., 1999).

Israel is using treated wastewater as irrigation water for a long time and Ministry of Health has published a public health circular about the properties of wastewater that can be allowed for irrigation. This act mainly contains the following items:

- Plants which are not allowed for wastewater irrigation: Cabbage, lettuce, spinach, strawberry
- Uncooked vegetables may be irrigated with water which have a BOI concentration less than 20 mg/l; fecal coliform concentration less than 25/100 ml for the 80 % of samples and minimum 72 hours must pass after irrigation before harvesting
- Fruits may be irrigated with disinfected secondary treatment plant effluent until two weeks before harvesting
- If cotton, sugar beet, soybean and leguminous seeds will be irrigated with secondary treatment plant effluent, there must be minimum 400 m between the irrigation sprayer and residential location (Çekliler, 1999).

3.3.3 Effects on Soil

Sodium, chloride ions, and bor that are found in domestic wastewater can damage some sensitive plants. Especially sodium ions can cause deflocculating of clay particles and formation of undesirable soil structure.

Organic materials in treated wastewater increase water capture capacity in light (sand) soils and cation exchange capacity and organic material content in silt and clay soils (DEU, Env. Eng., 1999).

3.3.4 Effects on Groundwater Quality

The impacts of allowing wastewater to infiltrate into the subsurface can have both positive and negative effects, but some degradation of groundwater quality can be anticipated. Municipal wastewater generally contains high levels of suspended dissolved organic and inorganic materials. Organic substances are likely to include carbohydrates, lignin, fats, soaps, synthetic detergents, proteins and their breakdown products. The physical characteristics of effluents can cause problems. Suspended solids may clog soil pores, coat the land surface and reduce water penetration and aeration (ODA, 1996).

The use of treated effluent reduces these problems, and also the organic material can be beneficial to the soil with good irrigation practices.

The content of nitrogen, phosphorus and potassium, as well as many nutrients, is likely to be high enough to supply crop requirements, eliminating the need for inorganic fertilizer addition. Excess nutrients, however may remain in the infiltrating water, since the total nitrogen content of wastewater is usually high, and large scale of wastewater recharge of aquifers can lead to unacceptable groundwater pollution with either ammonium or nitrate. Other inorganic constituents, such as sodium, chloride and sulphate may be present at concentrations that could inhibit agricultural usage and may also pose a threat to groundwater quality.

Domestic wastewater can contain many trace heavy metals, such as mercury and cadmium. Where there is also substantial input of industrial effluent, significant levels of other toxic elements may be present, together with organic compounds such as the chlorinated solvents.

The contaminants of most immediate concern to health are pathogenic micro- and macro-organisms: helminthes, protozoa, bacteria and viruses. Those, which exhibit a long persistence in the environment and have a low minimal effective dose, will pose the greatest risk. The larger pathogens, however, do not provide a threat to groundwater since they are filtered out in the soil, but pose a serious risk to farm workers exposed to wastewater and to consumers of the agricultural products (ODA, 1996).

3.4 Advantages and Disadvantages of Using Treated Wastewater as Irrigation Water

3.4.1 Advantages of Using Wastewater for Irrigation

Water used for municipal or industrial purposes leaves the cities as wastewater containing pollutants and constituents accumulated during its use. When the water is used for irrigation, most of the water applied evaporates from the soil, mainly by evapo-transpiration.

Mineral salts do not evaporate but remain in residual water, penetrate into underlying soil layers, and may be temporarily retained in the non-saturated layers eventually reaching groundwater aquifers.

Mineral salts are not removed in common wastewater processes, even in tertiary treatment. Only desalination processes such as reverse osmosis can reduce salinity content. Wastewater and effluents have much higher salinity content than water supplied to towns (Rebhun, 2003).

Many advantages arise from the use of effluents in agriculture as following:

a. Treated wastewater will serve in the long run as a key component to agriculture.

b. The supply of effluent is highly reliable quantity-wise (not necessarily with respect to quality) and increases with population growth.

c. The cost of treating secondary effluent is generally low, relative to the cost of fresh water or any other unconventional water sources.

d. The option of allocating effluent to irrigation is the best and cheapest option for effluent disposal in most cases from the viewpoint of environmental conservation; accordingly, it is preferred disposal alternative for the municipalities.

e. Secondary effluent contains nutrients such as nitrogen, phosphorous and potassium, which may save on the use of chemical fertilizers (Haruvy, 2000).

However, this advantage is conditional on proper quantities and timing, since excess or bad timing while providing of these nutrients, may negatively affect yields.

3.4.2 Disadvantages of Using Wastewater for Irrigation

Disadvantages of using treated wastewater for irrigation purpose are given below:

a. Quality Problems Affecting:

- Human health;
- Potential damage to crops and plantations;
- Potential damage to environment;
- Contamination of groundwater.

b. Problems Related to Irrigation System:

- Increased costs of construction and adaptation of the supply and the irrigation system to use of effluent (conveyance, storage, filters, etc.)
- Damage to performance of the irrigation equipment (clogging of drippers and micro-sprinklers, accelerated depreciation, etc.)

c. Increased Water Requirements Due To:

- Higher soil leaching requirements due to salinity;
- Water losses due to evaporation at storage reservoirs

d. Need for Continuous Follow-up and Control of Effluent Quality

(Haruvy, 2000).

CHAPTER FOUR
PRESENT SITUATION OF MENEMEN PLAIN

4.1 Study Area

Study area is in Aegean Zone, 20 km north-west of İzmir and it is surrounded with İzmir Bay and Tuzla on the south; Maltepe Hills on the west; Yarandağ, Karahasan Mountain, Oğlangölü Hills, Aegean Sea on the north and Yamanlar Mountain on the east.

Drainage area is 450 km^2; 128 km^2 of this area is plain.

Mediterranean climate is present in study area and average annual precipitation is 510 mm. Average temperature is 17 ^0C along the year (Akkuzu, Aşık, Ünal, Karataş, & Avcı, 2003).

Average hydraulic conductivity of the plain is 0.79 m/day (Toprak Su Genel Müdürlüğü, 1972).

Olive agriculture and animal feeding is very common on the mountainous section of the area (DSİ, 1981).

Most of the products in Menemen Plain are composed of field plants, in addition to vineyard-garden agriculture; vegetable and livestock actions are being done. Cotton is at the top of the list of irrigated plant kinds in the irrigation system, it includes average 80 % of irrigated area. Vineyard, vegetable and fruit, cereals, plantations and corn follow it (DEU, Env. Eng., 1999).

Menemen Plain has different soil characteristics in different regions. Pollution of soil by iron, zinc, copper, nickel, thallium, antimony, boron and relatively chromium is determined as a result of a study (DEU, Env. Eng., 1999).

Area usage classification, depth of the plain, erosion, soil constitution, soil group and salinity maps of Menemen Plain are given (Appendix 4).

4.2 Geology of the Plain

Study area and close zone of it is in the tectonic zone region that is called as "İzmir-Ankara Zone" in the frame of Turkey's "Signboard Tectonic Theory". As a result of the observations in the study area, the follwing formations are present:

- Bornova Utter that is composed of paleogenic sandstone-shale consecutives, sandstone-shale lenses, sandstone blocks and limestone blocks located as one stone.
- Land Settlements that is composed of neogenic gravel stone, sandstone, marn-siltstone-limestone consecutives those are settled in riverbeds, deltas and lake environments.
- Volcanic Units those composed of andesite, basalt, dasit, riolite and tufa and agglomerate which are proclastics of these.
- Alluvium Unit which is composed of quartener year old sandy, gravel clay or clay sand and gravel material those are composed of less rigid or not rigid levels are reserved.

Stratigraphic colon section (cross-section) that belongs to study area and its surrounding is shown in Figure 4.1 (Ateşli, 2002).

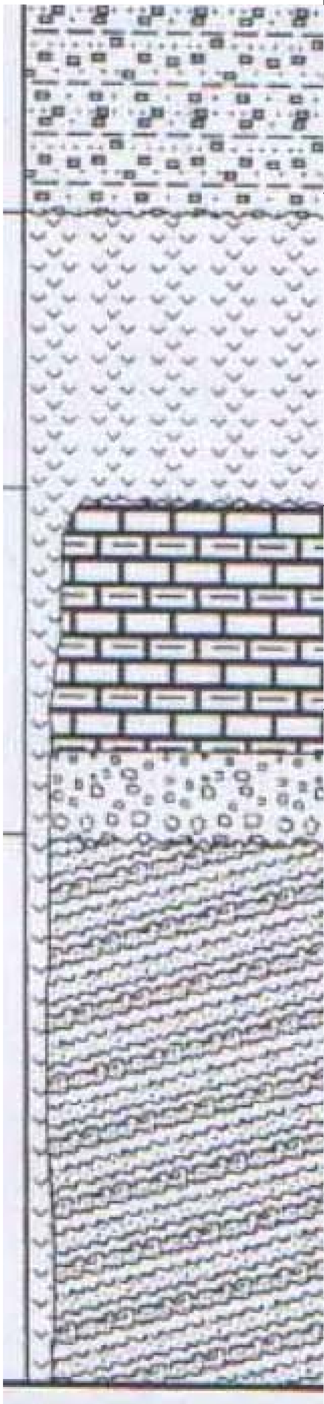
UPPER SYSTEM	SYSTEM	SUB SYSTEM	SERIES	UNIT NAME	SYMBOL	LITOLOGY	EXPLANATIONS
SENEZOIC	QUARTENER			ALLUVIUM			Clay, clay-sand, and gravel; not pressed
	TERSIER	NEOGENE	MIOSEN				DISCORDANT STRUCTURE White and weak tufa Red-grey colored, ortaç endured agglomerate Grey-pink fresh surface colored Hard, endured, abundant cracked andasite
		PALEOGEN	PALEOSENE				DISCORDANT STRUCTURE Yellow-white colored, medium-well endured limestone Yellow colored, bad-medium endured clay stone
MESOZOIC	CRETACEOUS						Sandstone, shale, bedrock gravel stone that contains limestone DISCORDANT STRUCTURE Brown fresh surface, red decomposition colored sandstone Green fresh surface, grey-brown decomposition surface colored shale consecutive

Figure 4.1 Stratigrophic colon section of study area (Ateşli, 2002)

Alluvium's thickness that is constituted by Gediz River changes between 10-200 m in Menemen Plain. Alluvium is generally above neogen, somewhere (near Buruncuk 2826, Süzbeyli 2824 wells) above magmatic rocks. Surface of the plain is generally covered with silt. The situation isn't present at the places covered with alluvium cones. Silt's thickness on alluvium is between 1-50 m. Clay, gravel sandy, clay-sand, clay-gravel levels are present below the silt in the plain. This gravel and sand levels are old Gediz Bed and they are connected with Gediz. Some of the recharge (feed) of this gravel, sand gravel aquifer that contains abundant groundwater is from Gediz River (DSİ, 1981).

The slope of the plain is generally between 0.1% and 1%. It is 2-6% for collovial sections and rise to 4% in alluvial sections, 10% at river hills. It is higher at high areas that surround the plain (DEU Env. Eng., 1999).

4.3 Hydrogeology of the Plain

Gediz is the most important river in the plain and it is the biggest river in northern Aegean region (Figure 4.2). Study area of this study is shown by red dots. The wetlands that Gediz river has formed are very important because of their ecological and biological
properties. The delta has a 40000 hectars area and 20.400 hectars area has wetland ecosystem; that makes the delta one of the most important coastal deltas in Turkey. The wetland ecosystem of the delta is protected by some speacial laws (Tosun, 2003)

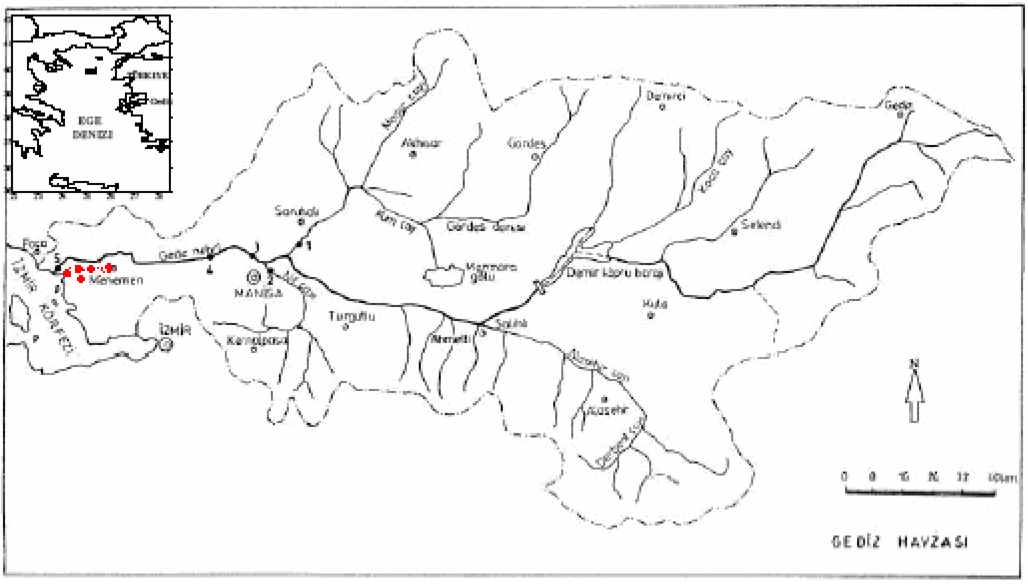


Figure 4.2 Gediz Basin (Tosun, 2003)

The Gediz River which arises from the south-east of the Gediz Town in the inside of the Agean Region is the second biggest river of the Agean Region and its basin covers %2.2 of the Turkey with its about 1.7 million hectare. It gets its source from the Murat and Şaphane Mountains in the Inside of West Anatolia Region. The distance that it travels over from its source up to the İzmir Bay where it is discharged about 350 km (Yavaş, Ö., 2001).

Drainage area of the river is 16.775 km. Average flow of Gediz River is 1950 hm^3/year according to 1998 data.

Gediz River enters to the study area from Emiralem Pass and reaches to Aegean Sea from the south of Maltepe. The length of the river in the study area is 35 km. River water is used for irrigation of Menemen Plain. A regulator has been built up which collects and delivers the river's water. This regulator is in Emiralem Section and 10 km far away from Menemen (Murathan, 1998).

Gediz River's water is divided to two as right and left shore and spreads to the plain with many branches. 16,000 hectares of Menemen Plain is irrigated with Gediz River.

As it can be seen from Figure 4.3 and Figure 4.4, flow rate of Gediz is decreasing, the reason being the negative affect of the decreasing precipitation in last years.

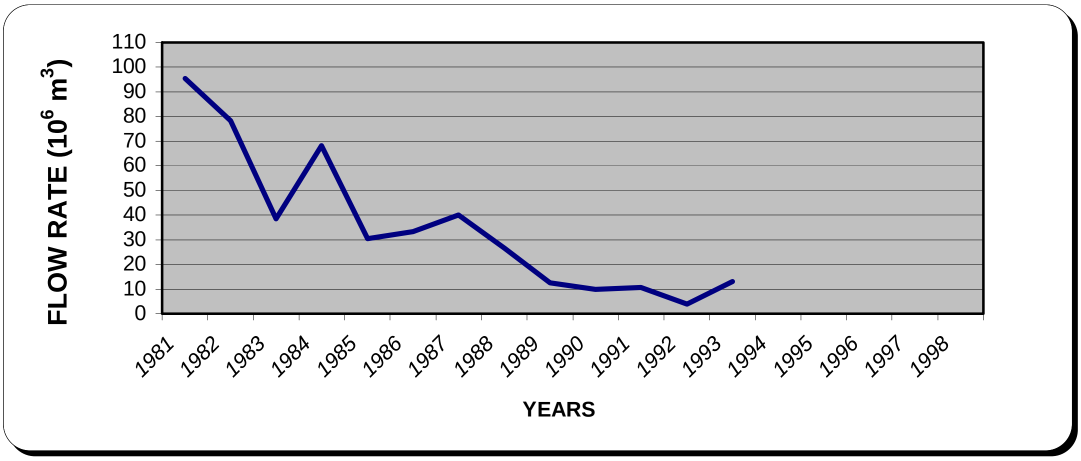


Figure 4.3 Gediz flow rate (Muradiye Bridge) (Murathan, 1998)

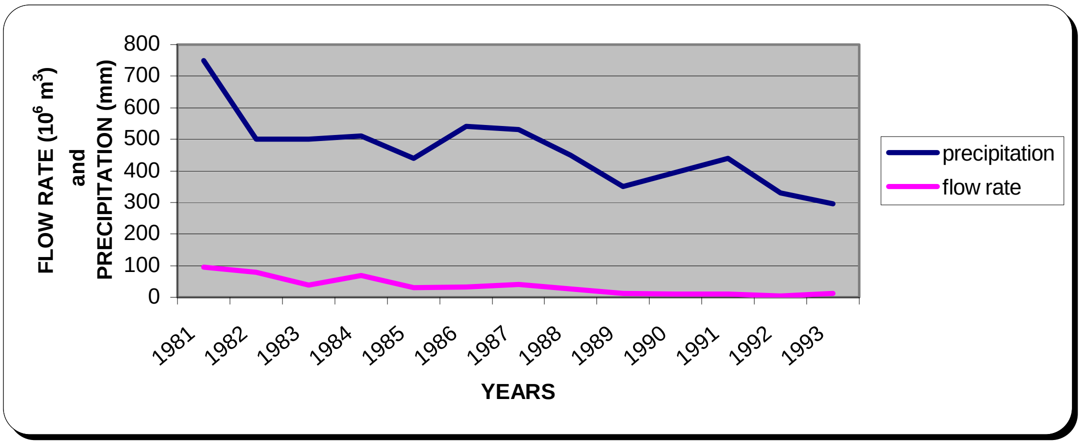


Figure 4.4 Relation between Gediz flow rate (Muradiye Bridge) and precipitation values (Murathan, 1998).

Parallel with this, water quantity that is used to irrigate Menemen Plain from Gediz River has decreased, too. Although there are many by-streams that enter to Gediz River, these streams don't carry water except rainy months. It can be said that groundwater is recharged from these streams.

There are lots of wells to obtain drinking, using and irrigation water that are opened by State Hydraulic Works (DSİ), General Directorate of Road Water and Electricity (YSE), Bank of Provinces and the public.

When hydrogeology of the plain is examined, it is seen that mostly an alluvium cone shaped structure has built up which is overlooked big alluvial settlements like sand-gravel with the affects of by-streams. Emiralem, Değirmen, Devedüşen, Buruncuk and Asarlık Streams are the main flood beds that contribute to settlement of the more alluvial material.

Alluvium, which is composed on a thick and widespread environment, show good aquifer property with sand and gravel. Groundwater balance is composed of directly infiltration of precipitation, precipitation from by-stream cones and infiltration from Gediz River bed.

There are a lot of shallow wells and drill wells that are opened on alluvium aquifer in Menemen Plain and it's surrounding. Shallow wells which are opened by the community to obtain domestic and irrigation water, generally take water from a depth of 4-6 m. Deep drill wells are opened by government associations (D.S.İ, Bank of Provinces, Y.S.E, İZSU) and by the community.

When the logs of the wells, which are opened to get water to İzmir Urgent Drinking Water Project by DSİ (State Hydraulic Works) in 1974 are examined; it is seen that the depth of the wells are between 80-170 m (Ateşli, 2002).

While equipping plans were being composed, electrical log is taken from the well and well equipping plans are composed by correlation of log values and fragment samples that were taken from every meter of the well. According to these equipping plans, the formations that have aquifer property are andezit, quarts, sand and gravel debris that have radiolit elements levels of the alluvium.

Table 4.1 Menemen Plain Static Groundwater Levels in April (N) and October (E) (Ateşli, 2002)

		19013	19014	19015	19016	19017	19018	19019	19020	19021	19022	19023	19024	19025	19026	17324	19024 A	2825 A
1974	N																	2,20
	E																	2,33
1975	N	4,30	4,60	3,09	3,43	3,24	3,342	4,61	4,55	4,70	3,42	5.52	4,85	4,85	3,43	4,02	5,25	1,35
	E			13,85														2,45
1976	N																6,35	1,83
	E																3,35	5,03
1977	N																11,50	6,10
	E																13,10	7,61
1978	N																12,41	7,20
	E			15,30	13,85 K		12,40 K		11,95	13,95	14,00 K	14,30 K	14,15 K		14,05 K	14,10 K	13,48	8,05
1979	N	11,40	18,10 M	11,30 M	15,20 M	14,35 M	15,30 M	13,55	14,40	15,60 M	16,10 M	15,2 M	15,90			15,80 M	15,66	9,74
	E	16,45	16,15	16,10	16,35	15,00	16,35	14,11	16,40	16,26	16,35	16,25	16,30		16,30		15,40	9,84
1980	N	14,20	14,00 M	13,60 M	13,60	14,10 M	13,00 M	12,40		14,30	14,25	14,25	13,50		14,00		14,30	8,64
	E												16,20 K				15,66	9,92
1981	N	15,80	16,00 M	14,75 M	14,10 M	14,00 M	15,00 M	12,20		14,80 M	15,80	15,00 M	15,25 M			14,50	14,32	10,02
	E	17,30	18,30 K	17,50 K	16,20	14,30 K	16,45 K	15,60		15,90 K	17,10 K	16,15 K			18,65 K		14,66	11,04
1982	N	16,75	13,60 M	17,00 M	15,90 K	15,10 M	16,10 M	12,65		14,70 M	19,20	13,60 M	15,45 M		18,75	15,90	14,55	9,98
	E	19,80	18,60	21,00	20,90	17,30 K	18,70	15,50	16,00 K	18,80	18,00	19,00	18,70		19,10	15,20	15,64	11,16
1983	N	19,80 (Mart)	18,10 M	20,60 M	20,50 M	17,20 M	17,60	15,00		18,30	19,05	18,70	19,00		15,80 M	16,50	17,15	11,92
	E	21,00	19,00	20,30 (Ekim)		18,00	18,80	17,00		19,00						19,20	17,55	12,40
1984	N	6,30 (Mart)	7,90	7,10		5,40 M		7,80	9,25 M	6,40	5,80	8,00 M	6,40		5,10	4,43	5,62	2,65
	E	5,70	8,40	6,20		4,60		8,65	7,00		4,20	7,00	5,60		4,65	6,10	7,50	2,53
1985	N	6,05 M	6,20	5,55 M		4,90	5,05	7,40	6,40	6,05	4,40	6,30 M				10,70	6,74	2,33
	E	8,00						8,60									5,87	3,48
1986	N	7,80 M		7,30 M				8,70		8,35	4,40	9,98			7,38 M		8,25	4,96
	E	13,94	13,98	12,93				12,40		16,80 MÇ		14,90 MÇ			13,50		14,60	10,40
1987	N	16,40 M						13,00							13,7 M		14,40	10,23
	E	16,80						14,00							15,90		16,98	12,75
1988	N	20,80 MÇ			17,60 M			13,65							16,80		17,18	13,13
	E	17,00			16,35			14,35									17,82	13,77
1989	N																18,72	14,65
	E																19,75	15,49
1990	N																19,91	15,57
	E																20,84	16,64
1991	N																20,23	16,45
	E																19,00	15,94
1992	N																	
	E																22,90	20,90
1993	N																22,00	17,68
	E																23,12	19,68
1994	N																22,44	18,48
	E																27,35	24,94
1995	N																22,70	20,65
	E																24,85	20,76
1996	N																23,00	19,89
	E																25,97	22,50
1997	N																29,05	23,90
	E																31,08	26,35
1998	N																25,65	21,42
	E																25,20	23,40

4.3.1 Groundwater Recharge and Abstraction

4.3.1.1 Groundwater Recharge:

Groundwater is recharged by precipitation, surface flow, Gediz River, irrigation water and seawater in Menemen Plain. Total drainage area of Menemen Plain is 450 km^2. 210 km^2 of this area is mountain and 240 km^2 plain area is composed of alluvium.

Recharge by Precipitation:

Precipitation Recharge of Alluvium: Alluvium area of Menemen Plain is 240 km^2. But 1/3 of surface is covered by silt and clay-silt; so there is no recharge from these areas. 20 % of precipitation is accepted as the amount of water, which can reach to the groundwater when the surface geology studies, lightologic property of alluvium, formations in wells and topographic condition are taken into consideration.

Alluvium = 160 km^2

Precipitation = 525.4 mm.

Filtration from precipitation = %20

Recharge by filtration from precipitation = $160 \times 10^6 \times 0.5254 \times 0.2 = 16.8 \times 10^6$ m^3 /year

Recharge by Flow: Intensity and duration of precipitation, values measured in flow observation stations and topography are taken into consideration while calculating the flow rate of precipitation that falls to the mountains. In this condition, flow coefficient can be taken as % 20 and ratio of filtration from flow can be taken as % 10.

Recharge by Flow = $210 \times 10^6 \times 0.5254 \times 0.2 \times 0.1 = 2.2 \times 10^6$ m^3/year.

(Murathan, 1998)

Recharge by Irrigation Water: 160 km^2 areas are irrigated by Gediz River in Menemen Plain. 1/3 of plain surface is covered by clay and clay – silt; so there is no recharge by irrigation water in this area. 60 x 10^6 m^3 / year irrigation water is used and filtration to groundwater can be accepted as % 10.

Recharge by Irrigation Water = 60 x 10^6 x 0.10 = 6 x10^6 m^3 / year.

Recharge by Gediz River: It is said that Gediz River recharged groundwater along 5.5 km in Menemen Plain Hydrogeologic Study Report, which is published in 1973. In those years, an important amount of river was above the groundwater level. 15-20 m. decreases are observed in the past times. As a result of decreases in the water level, it can be said that the river recharged the groundwater along 11 km(W).

T = 1500 m^3/day/m.
W = 11000 m.
I = 0.0035
L = 365 day
Q = amount of Gediz River recharge
Total Recharge
Q =1500 x 0.0035 x 11.000 x 365 =21.07 x 10^6 m^3/year

Recharge by Sea Water: Approximately in 70 km^2 areas on the south of the plain, there is salty water interference chemical analysis of the water which is taken from this area shows a % 5 sea water interference.
T = 1000 m^3/day /m. (Average of Tuzcullu, Süzbeyli wells)
W = 10 km.
I = 0.001
Q = Sea water interference
Q = T x W x I x t
Q = 1000 x 0.001 x 10.000 x 365
Q = 36 x 10^6 m^3/year (Murathan, 1998)

4.3.1.2 Groundwater Abstraction:

Groundwater is abstracted by evaporation, transpiration and artificial abstraction by wells.

Abstraction by Evaporation – Transpiration: Average area of groundwater level between 0 – 2 m is approximately 15 km².

Evaporation Area: 15 km²

Precipitation: 525.4 mm.

Evaporation is accepted as 50 %;

15 x 10 x 0.5254 x 0.05 = 3.9 x 10 ^{6} m³/year

Artificial Abstraction by Wells: Artificial abstraction is caused by İZSU wells, TÜPRAŞ wells, İller Bankası wells and irrigation wells, which are opened by public.

Total = 53.5 x 10^6 m³/year.

Table 4.2 Groundwater Balance (Murathan, 1998).

Recharge	*10^6 m^3/year	Abstraction	*10^6 m^3/year
Rain (alluvium)	16.8	Evaporation-Transpiration	3.9
Surface flow	2.2	Artificial abstraction by the wells	53.5
Irrigation water	6		
Gediz River	21.07		
Sea water	3.6		
TOTAL	49.7		57.4

Abstraction from plain is quite higher than recharge and is shown in Table 4.2.

Abstraction water affects the dynamic reserve further on safety reserve. Continuous decrease in groundwater level in the plain is caused by this abstraction.

One of the reasons of seawater interference in the plain is due to overabstraction (Murathan, 1998).

4.4 Water Quality

Physical, chemical hydrogeological and bacteriological properties of the water must be known before use and limit values should not be exceeded in usage.

Water quality is determined by analytic measurements of some materials that water contains. Chemical substances which are not wanted in water at high quantities are shown in Table 4.3; toxic materials that might be found in water and microbiologic properties and total microorganism number are given in Table 4.4 and Table 4.5 (Ateşli, 2002).

Table 4.3 Drinking water quality requirements (TS. 266,1997)

Properties	Class 1		Class 2
	Guide Level (GL)[4]	Maximum Allowable Concentration(MAC)[4]	Maximum Allowable Concentration(MAC)[4]
Nitrates, mg NO_3/l	25	50	25
Nitrites, mg NO_2/l	-	0.1	0.1
Ammonium, mg NH_4/l	0.05	0.5	0.05
Kjeldalh Nitrogen (except N in NO_2 and NO_3) mg N/l	-	1	1
Permanganate index (matters that can be oxidized by $KMNO_4$) mg O_2/l	2	5	5
Matters that can be extracted by chloroform, mg dry remainder/l	0.1	0.5	0.2
Dissolved or emulsified hydrocarbons (after petroleum ether extraction), mineral oils mg µg/l	-	2000 10	10
Phenols[1] as phenol index, µg c_6H_5OH/l	- 1000	0.5 2000	0.5 1000
Bore, µg B/l	-	200	200
Surface active matters (those give reaction with methylen blue), µg loril sulphate/l	50	200	50
Iron, µg Fe/l	20	50	20
Mangane, µg Mn/l	100[2] or	3000	100
Copper, µg Cu/l	3000[2]	5000	100
Zinc, µg Zn/l	100[3] or	5000	400
Phosphorus, µg P_2O_5/l	5000[3]		
Fluoride, µg F/l	400	1500[4]	1000
(8-12 ^{0}C)		700[4]	700
(25-30 ^{0}C)	-	1	0.5
Suspended solid, mg/l	-	300	100
Barium, µg Ba/l	mustn't be found	10[5]	10
Silver, µg Ag/l	100		
	-		

1) Matters that don't react with phenol.

2) At pump outlet or/and treatment processes and sub steps of these, this value is 100 µg Cu/l

- After a 12 hour wait of water in water system and at the arrival to the consumers, this value may be 3000 µg Cu/l
- Higher concentrations than 3000 µg Cu/l in water may cause a bad taste, colour change and corrosion.

3) At pump outlet or/and treatment processes and sub steps of these, this value is 100 µg Zn/l

- After a 12 hour wait of water in water system and at the arrival to the consumers, this value may be 5000 µg Zn/l
- Higher concentrations than 5000 µg Zn/l in water may cause a bad taste, iridescent and accumulations like sand.

4) MAC value changes according to the average temperature of related geographic site.

Table 4.4 Toxic substances those may be found in water (T.S. 266,1997)

Properties	Class 1		Class2
	Offered values (GL)	Maximum Allowable Values (MAC)	Maximum Allowable Values (MAC)
Arsenic, µg As/l	-	50	50
Cyanides, µg CN/l	-	5	5
Cadmium, µg Cd/l	-	50	50
Chromium, µg Cr/l	-	50	50
Mercury, µg Hg/l	-	1	1
Nickel, µg Ni/l	-	50	50
Lead[1)], µg Pb/l	-	50	50
Antimuan, µg Sb/l	-	10	10
Selenium, µg Se/l	-	10	10
Pesticides with relevant product, µg/l			
-Insecticides with organachlore, every matter one by one	-	0.1	0.1
-PCBs, every matter one by one	-	0.1	0.1
-Herbicides, every matter one by one	-	0.1	0.1
-Total of the substances above	-	0.5	0.5

1) 50 µg Pb/l value is given for flowing water.

- Lead concentration mustn't exceed 50 µg Pb/l in the samples that are taken after allowing water to flow, in systems that lead pipes are used. If the concentration exceeds the 100 µg Pb/l often and in important values after taking the sample directly or allowing to flow; suitable precautions must be taken to prevent the consumers.

Table 4.5 Microbiologic properties of water and total bacteria number (T.S. 266)

Properties	Class 1		Class 2
	Offered Values (GL)	Maximum Allowable Values (MAC)	Maximum Allowable Values (MAC)
Total bacteria number for drinking and usage water (except water in closed containers), in 1 mm sample			
- 37 ^{0}C	$10^{1)2)}$	40	-
- 22 ^{0}C	$100^{1)2)}$	500	-
Total bacteria number for water in closed containers[3)], in 1 mm sample			
- 37 ^{0}C	5	20	20
- 22 ^{0}C	20	100	100

1) These values, which correspond for disinfected water, must be quite low at the point that water leaves the treatment plant.

2) As taking consecutive samples, if one of these values is exceeding constantly, a control must be done.

3) MAC value must be measured by water, which is kept in a closed container at constant temperature in 12 hours.

Chemical Properties of Groundwater

Waters in various depths of groundwater contact with different soil structures which effect the water quality. Due to the dissolving degree of these units, less or more proportioned, dissolved materials mix with groundwater. Quantity of the dissolved materials changes according to connection time, flow rate of water, temperature of water and pressure. Also, rainwater dissolves some gases while falling down from the atmosphere and carries these materials to groundwater as it infiltrates to the soil. Dissolved substance in groundwater is usually more than surface water (Ateşli, 2002).

Important Ions in Groundwater

Appropriateness of groundwater for drinking, usage, spring water, industrial and irrigation aims and chemical qualities and usage aim is determined by measurement of anions and cations of water.

Calcium (Ca^{++}):

Ca quantity in the area changes between 0,4-30 mg/L in spring water; 48-89 mg/L in drill wells that are used to obtain drinking water. It is appropriate for T.S.266 limits. (Maximum quantity is 200 mg/L)

Magnesium (Mg^{++}):

Magnesium values are between 6-38 mg/L in spring water in study area and 28-44 mg/L in drinking water wells in Menemen Plain. It is appropriate to drink according to T.S.266.

Sodium (Na+).

Sodium values are between 5-40 mg/L in spring water wells in study area and 34-66 mg/L in drinking water drill wells in Menemen Plain.

Potassium (K+):

Potassium values are between 2-7 mg/L in spring water wells in study area and 4-7 mg/L in drinking water drill wells in Menemen Plain.

Bicarbonate ($HCO3^-$):

Bicarbonate values are between 12-391 mg/L in spring water wells in study area.

Chloride (Cl^-):

Chloride's source in groundwater may be seawater, evaporates, precipitation and atmosphere. Seawater is the source that gives the biggest amount of chloride to groundwater. Chloride concentration in groundwater decreases sharply along the distance from coast. Generally chloride quantity in groundwater is low in rainy environments and high in arid zones.

When water's chloride concentration is higher than 426 mg/ L, this water should not be used as irrigation water if it is not obligatory. It is harmful to use it for irrigation if its chloride concentration exceeds 710 mg/L.

Spring water chloride concentration is between 8-40 mg/L in study area and 34-62 mg/L in drinking water drill wells in Menemen Plain.

Sulphate (SO_4^{2-}):

Generally sulphate quantity in drinking water changes between 200-400 mg/L.

Sulphate quantity changes between 24-331 mg/L in the sources that are used for spring water; 42-111 mg/L in drill wells that are used to obtain drinking water.

Nitrate (NO_3^-):

Nitrate values are between 0-14 mg/L in drinking water drill wells in Menemen Plain (Ateşli, 2002).

Hazardous Substances in Groundwater

There are organic chemical substances and heavy metals in groundwater of the area, which are generally less than 1 mg/L. Table 4.6 shows these chemicals and its concentrations in drinking water drill wells in study area Menemen Plain.

Table 4.6 Hazardous chemicals in drinking water drill wells in Menemen Plain (Ateşli, 2002).

Lead (Pb)	Not determined
Cupper (Cu)	0.002 – 0.005 mg/l
Zinc (Zn)	0.056 – 0.29 mg/l
Selenium (Se)	Not determined
Mercury (Hg)	Not determined
Cadmium (Cd)	Not determined
Nickel (Ni)	Not determined
Silver (Ag)	Not determined
Barium (Ba)	0.087 – 0.14 mg/l
Aluminum (Al)	0.005 – 0.038 mg/l
Antimony	Not determined
Cyanide (CN)	0
Phenol	0
Ammonium	0
Phosphorus (P_2O_5)	0

Hardness

One of the most important properties of water is “hardness”. The reason of hardness of water is first of all calcium and magnesium bicarbonate ions and then calcium and magnesium sulphate, calcium and magnesium chloride, calcium and magnesium nitrate and a little iron, aluminum and strontium ions. Hardness or softness of water is noticed by foaming of soap in public.

Hardness of the water in study area is giveen in Table 4.7.

Table 4.7 Hardness of water in Menemen Plain (Ateşli, 2002).

Sample number	Place	Hardness	Class
51	Cansu	3.00	Very soft water
52	Değirmendere Bridge Spring	4.77	Very soft water
53	Filiş Tap	23.11	Quite hard water
54	E. Keskiner Tap	10.51	Soft water
55	Arık Spring	8.25	Soft water
56	Karagöl Tap	10.57	Soft water
57	Forest High Eng. Tap	3.44	Very soft water
58	Hortumlu Spring	3.39	Very soft water
59	İZSU Captage	3.9	Very soft water
61	Yengeçli Tap	11.07	Soft water
62	Adak Tap	3.79	Very soft water
63	Arzum Spring	7.25	Soft water
64	Özgür Tap	9.63	Soft water
66	Üç Kavak Tap	3.47	Soft water
M1	İZSU Menemen Well 1	23	Quite hard water
M14	İZSU Menemen Well 14	39	Hard water
M15	İZSU Menemen Well 15	40	Hard water
M16	İZSU Menemen Well 16	39	Hard water
M20	İZSU Menemen Well 20	37	Hard water
M21	İZSU Menemen Well 21	31	Quite hard water
M22	İZSU Menemen Well 22	31	Quite hard water
M T	Menemen Collecting Pool	32	Quite hard water
Ç 7	İZSU Çavuşköy Well 7	20	Little hard water
Ç 9	İZSU Çavuşköy Well 9	23	Quite hard water

Hydrogen Ion Concentration (pH)

In study area, pH values of waters that are taken from spring water wells change between 5.70 and 7.47. pH values of waters that are taken from drinking water drill wells in study area, in Menemen Plain change between 7.5 and 7.8 (Ateşli,2002).

Electrical Conductivity (EC)

Classification of waters due to their electrical conductivity is given in Table 4.8.

Electrical conductivity is electric transition property of substances and opposite of electrical resistance.

To determine the total dissolved ions in water, electrical conductivity is measured. Generally, conductivity is proportional with ion concentration until 50.000 micromho/cm; if dissolved material is high, EC values increase. EC values of waters in study area are given in Table 4.9 (Ateşli, 2002).

Table 4.8 Classification of water according to electrical conductivity (Ateşli, 2002).

EC (micromho/cm at $25^{o}C$)	Water Class
250 >	Very well
250 – 750	Well
750 – 2000	Useable
2000 – 3000	Suspicious
Higher than 3000	Not useable

Table 4.9 Classification of water according to electrical conductivity in Menemen Plain (Ateşli, 2002).

Sample number	Place	EC	Class
51	Cansu	134	Very soft water
52	Değirmendere Bridge Spring	227	Very soft water
53	Filiş Tap	619	Quite hard water
54	E. Keskiner Tap	246	Soft water
55	Arık Spring	286	Soft water
56	Karagöl Tap	336	Soft water
57	Forest High Eng. Tap	101	Very soft water
59	İZSU Captage	135	Very soft water
61	Yengeçli Tap	421	Soft water
62	Adak Tap	196	Very soft water
63	Arzum Spring	288	Soft water
64	Özgür Tap	633	Soft water
66	Üç Kavak Tap	183	Soft water
M1	İZSU Menemen Well 1	534	Quite hard water
M14	İZSU Menemen Well 14	835	Hard water
M15	İZSU Menemen Well 15	920	Hard water
M16	İZSU Menemen Well 16	822	Hard water
M20	İZSU Menemen Well 20	791	Hard water
M21	İZSU Menemen Well 21	681	Quite hard water
M22	İZSU Menemen Well 22	753	Quite hard water
M T	Menemen Collecting Pool	818	Quite hard water
Ç 7	İZSU Çavuşköy Well 7	528	Little hard water
Ç 9	İZSU Çavuşköy Well 9	593	Quite hard water

Classification of Waters According to Schoeller

Schoeller has classified waters according to their chloride, sulphate and carbonate-bicarbonate concentrations (meq/L).

According to Chloride Concentration

Schoeller’s classification according to chloride concentration is given in Table 4.10

Table 4.10 Schoeller's classification according to chloride concentration (Ateşli, 2002).

Cl Concentration (mg/L)	Quality of Water	Explanation
> 700	Hyper Chloride Water	
420 – 700	Chlorotalastic Water	Sea Water
140 – 420	Water Enriched by Chloride	
40 – 140	Medium Chloride Water	Maximum Cl in drinking waters is 40 meq/l
15 – 40	Oligo Chloride Water	
< 15	Ordinary Chloride Water	Cl is usually less than 10 meq/l in groundwater

Classification of waters taken from study area, according to chloride concentration is given in Table 4.11 (Ateşli, 2002).

Table 4.11 Classification of waters according to chloride concentration in Menemen Plain (Ateşli, 2002)

Sample number	Place	Chloride Concentration(meq/l)	Class
51	Cansu	0.45	Ordinary Chloride Water
52	Değirmendere Bridge Spring	0.56	Ordinary Chloride Water
53	Filiş Tap	0.59	Ordinary Chloride Water
54	E. Keskiner Tap	0.31	Ordinary Chloride Water
55	Arık Spring	0.31	Ordinary Chloride Water
56	Karagöl Tap	0.31	Ordinary Chloride Water
57	Forest High Eng. Tap	0.23	Ordinary Chloride Water
58	Hortumlu Spring	0.34	Ordinary Chloride Water
59	İZSU Captage	0.37	Ordinary Chloride Water
61	Yengeçli Tap	0.65	Ordinary Chloride Water
62	Adak Tap	0.73	Ordinary Chloride Water
63	Arzum Spring	0.65	Ordinary Chloride Water
64	Özgür Tap	1.13	Ordinary Chloride Water
66	Üç Kavak Tap	0.37	Ordinary Chloride Water
M1	İZSU Menemen Well 1	0.96	Ordinary Chloride Water
M14	İZSU Menemen Well 14	1.47	Ordinary Chloride Water
M15	İZSU Menemen Well 15	1.58	Ordinary Chloride Water
M16	İZSU Menemen Well 16	1.41	Ordinary Chloride Water
M20	İZSU Menemen Well 20	1.35	Ordinary Chloride Water
M21	İZSU Menemen Well 21	1.13	Ordinary Chloride Water
M22	İZSU Menemen Well 22	1.13	Ordinary Chloride Water
M T	Menemen Collecting Pool	1.75	Ordinary Chloride Water
Ç 7	İZSU Çavuşköy Well 7	0.9	Ordinary Chloride Water
Ç 9	İZSU Çavuşköy Well 9	0.96	Ordinary Chloride Water

Average chloride concentration, average sodium adsorption rate, average electrical conductivity and water class according to electrical conductivity and sodium adsorption rate of Menemen Plain groundwater is given in Table 4.12.

Table 4.12 Water properties in Menemen Plain (DSİ, 30.01.2004 -15.07.2004 Analysis)

PLACE	AVERAGE Chloride (mg/L)	AVERAGE SAR	WATER CLASS	AVERAGE EC*10^6 (micromho/cm)
Kesikköy	76.72	1.29	C2S1	680.33
Günerli	148.69	1.71	C3S1	932.00
Seyrekköy	135.22	2.47	C3S1	1014.50
Menemen Municipality Storage	95.72	1.46	C3S1	1354.00

Chloride concentration in Menemen Plain groundwater changes between 76.72 and 148.69 mg/L; sodium adsorption rate (SAR) is between 1.29 and 4.47 and electrical conductivity is between 680.33 and 1354.00 micromho/cm. It is second class irrigation water according to electrical conductivity in Kesikköy and third class in Günerli, Seyrekköy and Menemen Municipality. When sodium adsorption rates are examined; it is seen that groundwater is first class irrigation water. Groundwater's irrigation class according to both sodium adsorption rate and electrical conductivity is given in Figure 4.5.

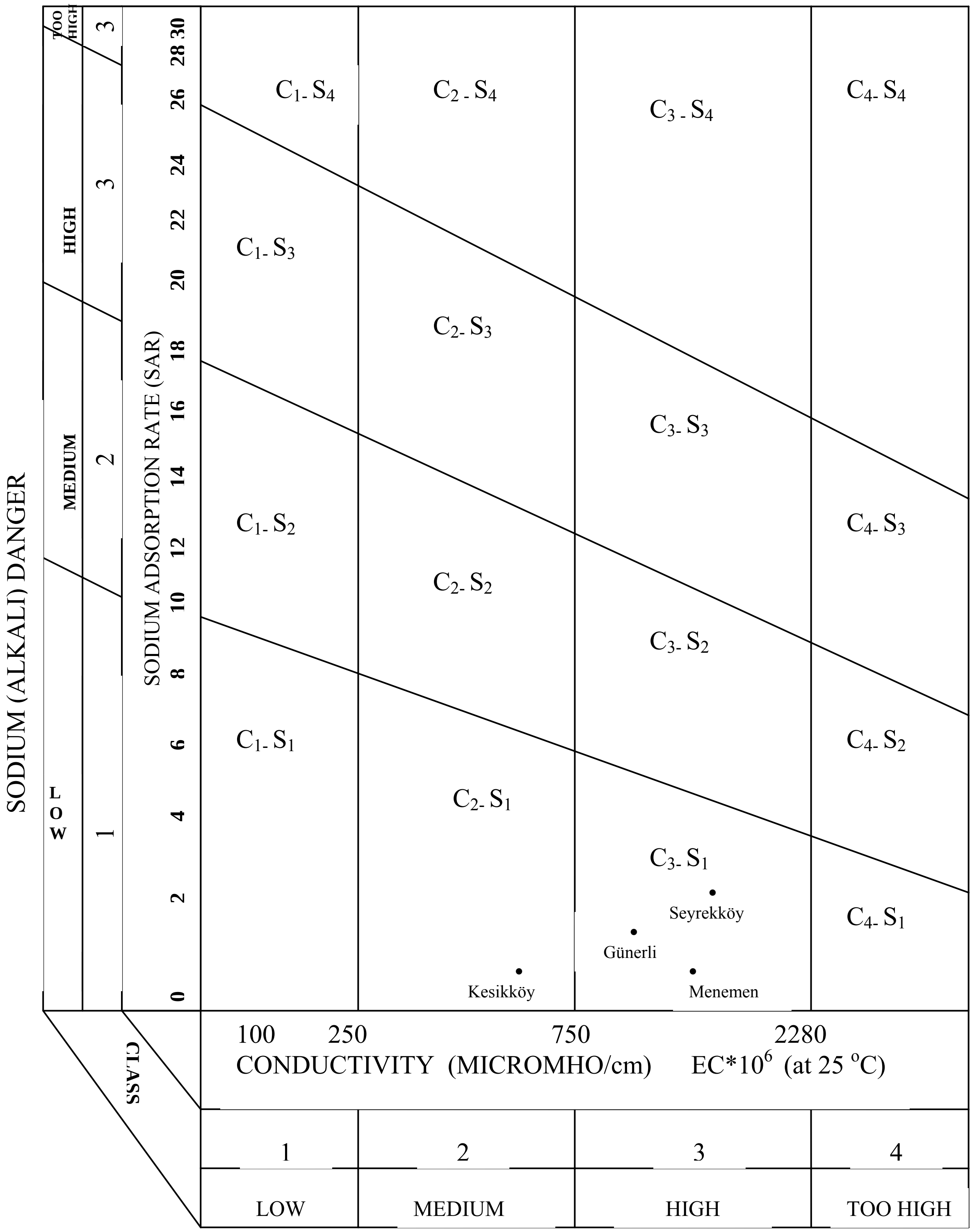


Figure 4.5 Classisfication of Menemen Plain Groundwater

CHAPTER FIVE
İZMİR MUNICIPAL WASTEWATER TREATMENT PLANT

5.1 İzmir Municipal Wastewater Treatment Plant Capacity

The wastewater originating from İzmir metropolitan area is collected and transferred via an interceptor canal to two treatment plants located to the north and southwest of the city. The southwestern plant is a small unit that is constructed to serve the southwestern portion of the city. The rest of the city is served by the northern treatment plant, which is called the İzmir Wastewater Treatment Plant (IWTP) within the scope of this study. A main interceptor that runs along the shoreline and spans the entire bay serves the IWTP. This main interceptor generally operates at atmospheric pressure under free gravity flow conditions. At the end of the interceptor, the northern treatment plant is constructed in the Menemen Plain where it is only a few kilometers away from the irrigation network serving the plain. The IWTP not only receives about 80% of all the domestic wastes of about 3.5 million populations but also the pre-treated wastewaters of numerous industrial establishments situated within the city. The plant implements extended-aeration activated sludge system to biologically treat an average flow rate of 7 cubic meters per second before ultimately discharging the treated effluents to İzmir Bay (Gündüz, Türkman, & Doğanlar, 2005)

İzmir Wastewater Treatment Plant works as activated sludge biologic treatment and phosphorus and nitrogen treatments are also applied. İzmir Wastewater Treatment Plant is built in a delta which contains Gediz River's old bed in Çiğli-Tuzla section, on a 300 000 m^2 area. Plant has 3 parallel lines. First line started to work in 25 January 2000, second one started to work in 26 September 2000 and the third line started to work in 12 August 2001 (İZSU, 2005).

5.2 İzmir Municipal Wastewater Treatment Plant Influent Values

İzmir Municipal Wastewater Treatment Plant's influent values are given in Table 5.1. Influent of the plant generally demonstrates typical characteristics of domestic wastewater. However, it has been further observed that the influent water shows very high levels of electrical conductivity and salinity. These high values are mainly attributed not only to salt water intrusion due to failing pipes and improper pipe connections along gravity flow sections of the interceptor canal but also to highly-concentrated pre-treated discharges of various industries within the city (Gündüz, Türkman, & Doğanlar, 2005). As it can be seen from the table; average salinity of influent is 4.19 % between January 2003 and August 2004. It is a high value when compared with irrigation water standards.

5.3 İzmir Municipal Wastewater Treatment Plant Effluent Values

İzmir Municipal Wastewater Treatment Plant's effluent values are given in Table 5.2. Although treatment efficiency is 84.27 % for COD, 90.56 % for BOD and 96.88 % for settled solids; it is only 2.99 % for salinity. This shows that the salinity of wastewater does not change much by the treatment methods, which are being applied in İzmir Municipal Wastewater Treatment Plant.

Table 5.1 İzmir Wastewater Treatment Plant Influent Values (İZSU, 2005).

INFLUENT 2003-2004

2003	COD mg/lt	BOD mg/lt	Sett.Sold. ml/lt	Sus.Sold. mg/lt	pH	conduct. μs/cm	Salinity %	Total-P mg/lt	PO4-P mg/lt	Total-N mg/lt	NH4-N mg/lt
Jan03	290,89	137,86	2,10	169,37	7,69	7087,10	3,98	6,59	5,22	34,28	20,15
Feb03	214,04	109,17	1,57	144,70	7,84	5466,70	2,87	5,92	3,50	28,31	15,94
Mar03	344,91	160,00	1,66	160,49	7,76	5949,33	3,17	7,64	4,42	33,89	22,07
Apr 03	460,92	185,19	2,31	199,01	7,79	6558,97	3,73	7,91	4,38	31,31	22,03
May 03	498,38	246,00	1,76	272,26	7,69	7215,38	4,22	8,72	4,54	32,69	21,98
Jun 03	454,81	220,00	1,83	187,53	7,79	8941,07	4,99	7,74	4,69	27,95	21,50
July 03	512,50	199,20	1,96	196,57	7,30	9266,23	5,54	7,67	5,20	30,11	20,58
Aug03	519,38	192,31	3,47	208,65	7,73	7881,48	4,90	8,03	4,94	31,78	20,77
Sep 03	509,00	206,67	3,57	237,48	7,64	7348,89	4,55	8,70	5,27	36,32	23,12
Oct03	539,96	203,70	3,44	269,28	7,60	7284,62	4,50	8,95	5,12	39,69	20,39
Nov 03	494,26	210,40	4,93	248,04	7,07	7777,00	4,82	7,17	4,21	34,73	17,01
Dec03	395,61	208,24	4,64	225,13	6,92	8740,00	4,12	7,63	4,29	32,27	18,03
Jan04	347,65	164,21	3,54	207,95	7,75	7346,67	4,00	6,61	3,41	26,54	-
Feb04	353,42	177,39	2,13	149,45	-	6531,67	3,50	7,47	-	34,34	-
Mar 04	453,61	242,96	2,65	194,65	-	-	-	8,72	-	39,42	-
Apr 04	438,60	221,74	3,15	192,24	7,85	6750,00	3,63	10,02	-	44,17	-
May 04	504,81	220,77	11,68	242,32	7,79	7816,40	4,30	9,75	3,65	40,14	-
Jun 04	377,52	202,22	2,76	237,99	7,64	7022,69	3,88	9,42	-	42,21	-
July 04	266,88	160,00	2,13	227,46	7,42	7564,23	4,20	8,62	5,55	39,68	13,18
Aug04	464,78	211,67	1,96	263,41	7,16	8140,71	4,79	7,92	5,30	37,65	10,73
Average	422,10	193,98	3,16	211,70	7,58	7404,69	4,19	8,06	4,61	34,87	19,11

Table 5.2 İzmir Wastewater Treatment Plant Effluent Values (İZSU, 2005).

EFFLUENT 2003-2004

	COD mg/l	BOD mg/l	Sett.Sold. mg/l	Sus.Sold. mg/l	pH	Electrical conduct. µs/cm	Salinity %	Total-P mg/l	PO4-P mg/l	Total-N mg/l	NH4-N mg/l	NO3-N mg/l
Jan 03	87,66	26,04	0,10	72,45	7,37	6315,51	3,61	5,47	3,93	20,56	3,73	5,88
Feb.03	55,87	17,71	0,10	51,01	7,48	5196,28	2,71	4,30	3,02	15,17	2,68	6,67
Mar.03	109,13	34,38	0,10	147,20	7,57	5485,89	2,90	6,60	3,09	20,32	2,63	6,87
Apr.03	136,25	33,93	0,10	120,29	7,72	6471,95	3,60	6,23	2,97	15,53	1,70	7,78
May.03	112,17	24,75	0,10	108,78	7,66	7173,85	4,12	5,43	3,26	11,24	1,16	4,40
June03	104,81	14,70	0,10	59,86	7,70	8709,29	4,90	5,35	3,70	11,08	1,96	5,36
July 03.	107,43	11,27	0,10	58,74	7,35	9043,62	5,47	5,12	4,36	9,39	1,22	4,65
Aug.03	84,71	7,40	0,10	40,66	7,70	7767,16	4,79	5,27	4,58	6,63	0,76	2,61
Sep.03	45,21	6,85	0,10	34,68	7,35	7196,30	4,40	5,82	5,12	7,82	1,42	2,52
Oct.03	35,76	9,44	0,10	15,94	7,33	7194,49	4,42	5,63	5,00	8,39	2,81	2,99
Nov.03	40,01	10,13	0,09	20,43	6,78	7659,82	4,73	4,33	3,85	6,82	1,77	2,64
Dec.03	48,43	15,41	0,09	25,29	6,56	7054,09	4,09	3,64	3,19	7,96	1,42	4,08
Jan.04	43,94	13,61	0,10	11,70	7,38	7391,54	4,09	-	4,12	10,27	0,66	7,82
Feb.04	44,77	14,78	0,10	22,26	-	6300,00	3,40	-	4,10	-	1,07	6,75
Mar.04	63,61	21,05	0,10	9,93	-	-	-	-	4,66	-	4,68	8,79
Apr.04	43,41	29,35	0,10	6,75	7,52	6472,22	3,52	-	4,72	-	1,28	5,15
May.04	62,67	25,19	0,10	16,61	7,32	7404,53	4,09	6,58	5,45	-	2,03	5,33
June 04	32,42	14,33	0,10	22,92	7,30	6795,38	3,75	-	5,80	-	2,82	4,63
July 04	25,40	16,90	0,10	18,32	7,01	7306,67	4,03	7,11	5,79	8,44	0,41	3,86
Aug.04	43,98	18,91	0,10	25,32	6,84	8055,70	4,70	5,24	5,28	7,09	1,45	2,92
Average	66.38	18.31	0.10	44.46	7.33	7104.96	4.07	5.47	4.30	11.11	1.88	5.09

5.4 Wastewater as Irrigation Water

In Turkey, 4.6 million hectare area was irrigated in 1999, a figure that will increase to about five million hectare area by the end of the 2005. Total water use in Turkey reached 38.9 million cubic meters in 1988, 75% of which was consumed by agriculture (Aslan, Türkman, 2005).

12,32 % of Turkey's agriculture area is in Aegean Zone. This is equal to 3,204,470 hectares. Total of surface water and groundwater resources of Aegean Zone is 22,252.5 hm^3 / year. İzmir's total surface and groundwater resource is 2,564 hm^3 / year. 2,070 hm^3 / year of this value is surface water and 494 hm^3/year is groundwater. Economical usable irrigation area in Aegean Zone is 1,946,44 ha but only 56.78% of this area is irrigated; 43.22% is not irrigated (Ministry of Agriculture and Rural Affairs, 2006).

Gediz River's precipitation area is 17118 km^2. Average flow per year is $1.95*10^6$ m^3 and 107.5 mm and 58.6 m^3/sec (National Emvironmental Action Plan, 1997).

In Menemen Plain (including Salihli, Turgutlu, Gediz, Mesir, Sarıkız, Gökkaya, Ahmetli, Üzümlü, Bağ, Sarıgöl), net irrigation area was 109,263 ha and irrigation ratio was 64% before 1996 (Anonymous, 1996). Irrigation water requirement was calculated as 78.7 hm^3/year in 1999 (DEU, Env. Eng., 1999).

In 2003, net irrigation area in Menemen Right and Left Shores was 22865 ha but only 19006 ha (83 % of net irrigation area) was irrigated with 168,699 hm^3 water (Karagöz, E., 2006).

The figures given above indicate the requirement of irrigation water in the area. Therefore, İzmir Wastewater Treatment Plant effluent is required by the farmers to be used in irrigation.

An important portion of existing water reuse systems use treated wastewaters for agricultural purposes. Irrigation water quality is more flexible depending on usage purpose. However, treated wastewater that is going to be used as agricultural irrigation water must has some properties depending on plant pattern. Treated wastewater which is going to be used; mustn't have negative effects on product quality, yield, groundwater and soil properties; health of farmers, agriculture workers and consumers of these products (DEU Env. Eng., 1999).

When the treated wastewater will be used for irrigation, it is necessary to follow the quality of treated wastewater, which is going to be used for irrigation, periodically at the exit of treatment plant. Also groundwater must be followed to observe the changes in water quality and amount of treated wastewater.

Since many different irrigation systems are present, it is necessary to choose the system which has the minimum risk. Surface and sprinkler irrigation systems pose health risks, canal and underground systems may cause salt problems, drop irrigation has fewer problems although its first investment cost is high. Success in using treated wastewater for agricultural purposes can be achieved by applying a comprehensive management plan, which contains water, area and soil management (DEU Env. Eng., 1999).

5.5 Evaluation İzmir Municipal Wastewater Treatment Plant's Effluent as Irrigation Water

DSİ (State Hydraulic Works) had a project about irrigation of Menemen Plain with effluent of İzmir Municipality Wastewater Treatment Plant, but later it was postponed because of insufficient technical features. This project was composed of three steps. In the first step, west of Şimal Discharging Channel would be irrigated. There is no drinking water well in the west side of this channel. Second step was west side of Seyrekköy Seconder Channel including Kesikköy, Seyrekköy, Günerli, Çavuşköy and Musabey. The third step was all west side of Ulucak Seconder

Channel. There are drinking water wells in areas considered in second step and third step. Appendix 5 shows these chanells in the plain (Atış, 2004).

Table 5.3 shows the effluent characteristics of İzmir Municipal Wastewater Treatment Plant and average chloride concentration is 1892.46 mg/l. It is fifth class water according to irrigation water standards. If this water is used for irrigation, it will reach to groundwater, which is used to obtain irrigation water and will affect the quality of the groundwater. Because of this, calculations must be done carefully by considering the hydrogeology, geology, meteorology, and soil structure of the plain to use treatment plant's effluent as irrigation water.

Table 5.3 İzmir Treatment Plant effluent values (İZSU, 2005).

PARAMETERS	14.03.02	30.04.02	03.07.02	18.08.02	31.01.03	25.03.03	11.08.03	17.10.03	10.12.03	07.01.04	15.03.04	26.03.04	AVERAGE
Conductivity (mS/cn)	7,34	7,54	8,43	9,18	4,39	4,70	8,33		7,46	6,49	5,07	5,38	6,76
Exchangable Na%	78,50	86,80	72,00	78,00	73,12	69,00	71,60	66,00	71,00	67,00	69,70	73,30	73,00
SAR	20,77	90,47	14,88	20,00	14,63	12,01	18,55	12,15	15,67	12,68	13,02	15,16	21,67
Residual Sodium Carbonate (RSC)(meq/L)	0,79	0,86	0,72	0,78	0,73	0,69	0,72	0,66	0,71	0,67	0,70	0,73	0,73
Chloride Ion (mg/l)	2090,00	2200,00	2465,00	2675,00	1190,00	1175,00	2460,00	2050,00	2050,00	1750,00	1227,50	1377,00	1892,46
Sulphate (mg/l)	420,00	275,00	350,00	590,00	210,00	360,00	350,00	350,00	372,00	361,40	231,20	255,00	343,72
Total Salt (mg/l)	3680,00	3770,00	4220,00	4600,00	2100,00	3350,00	4165,00	3510,00	3730,00	3240,00	2530,00	2690,00	3465,42
T. Bor (mg/l)	0,02	not determined	0,07	not determined	0,30	0,44	0,15	not determined	0,37	0,23	0,77	0,84	0,35
Irrigation Water Class	4.class (C4S4)	4.class (C4S4)	4.class (C4S2)	4.class (C4S3)	4.class (C4S2)	4.class (C4S3)	4.class (C4S3)	4.class	4.class	4.class	4.class	4.class	
Nitrate (mg/l)	19,90	10,90	1,10	6,30	14,90	22,10	4,40	10,60	21,50	22,10	22,00	27,00	15,23
BOI (mg/l)	27,00	28,00	36,00	35,00	15,00	10,00	20,00	20,00	35,00	30,00	15,00	22,00	24,42
COD (mg/l)		102,00	119,00	132,00	63,00	36,00	74,00	56,00		114,00	48,00	66,00	81,00
Total Suspended Solid (mg/l)	2,00	17,00	4,00	9,00	2,00	12,00	4,00	6,00	7,00	13,00	5,00	6,00	7,25
pH	7,53	7,21	7,41	6,99	7,61	8,30	7,77	7,36	7,16	7,85	7,40	7,77	7,53
T.Aliminium (Al) (mg/l)	not determined		not determined	not determined	not determined	1,01	0,04	not determined		not determined	0,19	0,04	0,32

Table 5.3. İzmir Treatment Plant effluent values (continued).

PARAMETERS	**14.03.02**	**30.04.02**	**03.07.02**	**18.08.02**	**31.01.03**	**25.03.03**	**11.08.03**	**17.10.03**	**10.12.03**	**07.01.04**	**15.03.04**	**26.03.04**	**AVERAGE**
T. Arsenic(As) (mg/l)	0,01		0,03	0,02	0,01	0,05	0,01	0,01		0,01	0,01	0,01	0,01
T.Berilium(Be) (mg/l)	not determined		not determined	not determined	not determined	0,01	not determined	not determined		not determined	not determined	not determined	0,01
Total Cadmiium(Cd) (mg/l)	not determined		not determined	not determined	not determined	not determined	not determined	not determined		not determined	not determined	not determined	
Total Chrom (Cr)(mg/l)	not determined		not determined	0,00	not determined	not determined	not determined	not determined		not determined	not determined	0,01	0,00
T.Cobalt(Co) (mg/l)	not determined		not determined	not determined	not determined	not determined	not determined	not determined		not determined	not determined	not determined	not determined
T.Cupper (Cu)(mg/l)	0,02		0,00	not determined	not determined	not determined	0,00	not determined		not determined	not determined	not determined	0,01
Floride (F)(mg/l)	0,22		not determined	0,73	0,21	not determined	0,76	0,40		0,04	0,28	0,35	0,37
T.Lead (Pb) (mg/l)	0,61		0,62	not determined	0,10	0,46	0,22	0,00		not determined	0,00	not determined	0,29
T.Litium (Li) (mg/l)	not determined		not determined	not determined	not determined	not determined	0,00	0,02		0,01	0,03	0,03	0,02
T.Mangane (Mn) (mg/l)	0,02		not determined	0,14	0,02	0,04	0,02	0,03		not determined	0,00	0,03	0,04
T.Molibden (Mo) (mg/l)	0,05		0,32	not determined	0,08	0,04	0,05	not determined		not determined	not determined	not determined	0,11
T.Nicel(Ni) (mg/l)	not determined		not determined	not determined	not determined	not determined	not determined	not determined		not determined	not determined	0,01	0,01
T.Selenium (Se) (mg/l)	not determined		0,02	0,01	not determined	0,01	not determined	not determined		not determined	not determined	not determined	0,01
T.Vanadium (Va)(mg/l)	not determined		0,00	0,00	not determined	not determined	0,00	not determined		not determined	not determined	not determined	0,00
T.Zinc (Zn)(mg/l)	not determined		not determined	not determined	not determined	not determined	not determined	0,10		0,09	0,01	0,05	0,06
T.Iron (Fe)(mg/l)	not determined		0,03	0,48	not determined	0,04	0,03	0,24		0,69	0,37	0,24	0,26

CHAPTER SIX
VULNERABILITY

6.1 Vulnerability of an Aquifer

Groundwater is usually high quality water. This is because of the natural filtration, which occurs during the flow of water through the layers of the soil. Contamination to groundwater depends both soil and contaminant types (Karataş, Panahi, & Aşık, 1999).

In any given area, the groundwater within an aquifer, or the groundwater produced by a well, has some vulnerability to contamination from human activities (Geological Survey, 2006).

Sensitivity of soil does not neccessariliy mean there is a high risk of groundwater contamination. Good water managment, low application rates reduce the risk of groundwater contamination. The opposite of these conditions can increase the risk even on soils that are not particularly sensitive (Huddleston, 1996).

Vulnerability is not a property of aquifer that can be directly measured. It is defined according to measurable properties and provide relative evaluation. Vulnerability maps can be prepared with the results (Ertekin, C., 2004).

The three classes of methods for assessing groundwater vulnerability range in complexity from a subjective evaluation of available map data to the application of complex transport models. Each class has characteristic strengths and weaknesses that affect its suitability for particular applications (Committee on Techniques for Assessing Ground Water Vulnerability [CTA], 1993).

Overlay and index methods involve combining various physical attributes (e.g., geology, soils, depth to water table, well locations). In the simplest of these methods, all attributes are assigned equal weights with no judgment being made on their relative importance. Thus areas where specified attributes mutually occur (e.g., sandy soils and shallow ground water) are rated as more vulnerable. These methods were the earliest to be used in assessing ground water vulnerability and are still favored by many state and local regulatory and planning agencies. Overlay and index methods that attempt to be more quantitative assign different numerical scores and weights to the attributes in developing a range of vulnerability classes which are then displayed on a map.

Approaches using process-based simulation models require analytical or numerical solutions to mathematical equations that represent coupled processes governing contaminant transport. Methods in this class range from indices based on simple transport models to analytical solutions for one-dimensional transport of contaminants through the unsaturated zone to coupled, unsaturated-saturated, multiple-phase, two- or three-dimensional models. These approaches are distinguished from others in that many of them attempt to predict contaminant transport in both space and time (CTA, 1993).

Statistical methods generally use a contaminant concentration or a probability of contamination as the dependent variable. These methods incorporate data on known areal contaminant distributions and provide characterizations of contamination potential for the specific geographic area from which the data were drawn. Statistical methods have been developed with the availability of data keenly in mind and are designed to deal with data of varying quality and types. They do not attempt to define processes or cause-effect relationships, and results are expressed as probabilities. These methods have been used in the definition and characterization of assessment areas and the assessment of vulnerability using probability models. Statistical approaches vary in complexity and generally include multiple independent variables (CTA, 1993).

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There are different methods to evaluate the vulnerability of an aquifer. These methods are interested with hydrogeology parameters and geology of the aquifer. GOD is one of these methods which is developed for alluvium plains. DRASTIC has a large literature because of different geologic condition applications. EPIK method is developed for carstic mediums (Ertekin, C., 2004).

Low flow rate of groundwater in an aquifer is an important factor in groundwater pollution. Because of too slow flow rate (less than 30 m/year) a polluted aquifer may stay polluted for hundreds of years. If an aquifer, which is used to supply drinking water, is polluted; it is necessary to leave the wells and to open the new ones in long distances or to search alternative surface sources (Karataş, Panahi, & Aşık, 1999).

Fine textured soils – silty clays and clays – generally have low sensitivities because they have slow or very slow permeabilities and high sorption potentials. Medium textured soils – silt loams, silty clay loams, loams, and clay loams – generally have low to moderate sensitivities, even in humid areas, because they have relatively slow permeabilities and relatively high sorption potentials. Coarse textured soils – sands, loamy sands, and sandy loams – generally have moderate to high sensitivities because they are more permeable and tend to have lower sorption potentials. Organic soils – those that consist almost entirely of decomposed plant material – have extremely high sorption potentials. Thus the cultivated organic soils have low sensitivities (Huddleston, 1996).

High concentrations of organic matters in wastewater, which is used for irrigation, may have negative effects on plant growth because it consumes oxygen in the root of the plant. Suspended solids in water may increase the yield of the soil. However, if rain irrigation method is used, suspended solids can be harmful for plants and system.

Suspended solids cause negative effects like decrease in profit life of water storage buildings, alluvial collections on productive areas, decrease in irrigation and drainage capacities, limitation in life in water, decrease in quality of recreational waters, increase in water treatment costs, movement of agricultural sourced chemical matters with sediments in water. Suspended solids are not directly harmful for human health; but they are indirectly harmful because they can carry bacteria and other toxic compounds. Suspended solids, which are often in organic form in wastewater, also negatively affect the chlorination efficiency (Aşık, Karataş, & Panahi, 2001).

Chlorination is applied to remove the pathogenic organisms, to protect human health and to prevent negative effects during wastewater storage and application. Disinfection of wastewater with chloride constitute harmful by-products like trihalomethanes (chloroform, bromodichloromethane, dibromochloromethane and bromoform) as a result of reaction with humic acid, fulvic acid and boron. Especially in sprinkler irrigation, chloride, which may remain on plant, causes problems. Degree of this harm, which is constituted by absorbing from the leaf in rain irrigation, may increase if irrigation is applied in day hours with high temperatures and with slowly turning sprinkler caps. This negative effect can be decreased by irrigating at nights and with fast turning caps (Aşık, Karataş, & Panahi, 2001).

Even in the very well operating treatment plants, the pathogenic microorganisms, although their concentration is decreased as exponentially, can't be removed totally. Virus and protozoa parasite levels were determined too high in chloride-disinfected wastewater in a research conducted in Egypt's Minuf City. Enteric pathogens which are present in these waters may continue their lives in soil, water or on plants.

Treated wastewaters contain heavy metals like cadmium, chromium, lead, copper, mercury, nickel and zinc. But they rarely exceed the standards, which are offered as irrigation water quality criteria (Aşık, Karataş, & Panahi, 2001).

CHAPTER SEVEN

MATERIAL AND METHOD

7.1 DRASTIC Model

There has been a growing interest in simulating the state and dynamics of soil water during the past two decades in response to need to develop solutions for various agricultural and environmental management problems, such as designing irrigation and drainage systems, and controlling pollution of surface and groundwater resources. Models can be used to guide future research efforts in the sense that they can be used to aid testing of hypotheses and exposure of areas of incomplete understanding (Parsinejad, 1998).

In this study, DRASTIC model decided to be used to evaluate the vulnerability of groundwater to pollution in Menemen Area.

DRASTIC was developed by EPA to be a standardized system for evaluating groundwater vulnerability to pollution. The primary purpose of DRASTIC is to provide assistance in resource allocation and prioritization of many types of groundwater-related activities and to provide a practical educational tool. DRASTIC considers seven hydrologic factors: Depth to water, net recharge, aquifer media, soil media, topography (slope), impact of vadose zone media and hydraulic conductivity of the aquifer. Each of the hydrogeological factors is assigned a rating from 1 to 10 based on a range of values. The ratings are then multiplied by a relative weight ranging from 1 to 5. The most significant factors have a weight of five; the least significant have a weight of one. Rate and weight of a factor are multiplied by each other and the results of these multiplications of each factor are summed. Ranges and ratings for the hydrogeology factors are shown in Table 7.1, Table 7.2, Table 7.3, Table 7.4, and Table 7.5. The smallest possible DRASTIC index is 23 and the largest is 226 (Osborn, Eckenstein & Koon, 1998).

DRASTIC Index

23 Less Vulnerable ⟷ More Vulnerable 226

Table 7.1 Ranges and ratings for depth to water

D-Depth to Water		
Range		**Rating**
Feet	**Meters**	
0-5	0 – 1.55	10
5-15	1.55 – 4.65	9
15-30	4.65 – 9.30	7
30-50	9.30 – 15.50	5
50-75	15.50 – 23.25	3
75-100	23.25 – 31.00	2
100 +	31 +	1
Weight: 5		

Table 7.2 Ranges and ratings for net recharge

R-Net Recharge		
Range		**Rating**
Inches	**Meters**	
0-2	0 – 0.051	1
2-4	0.051 – 0.10	3
4-7	0.10 – 0.18	6
7-10	0.18 – 0.25	8
10 +	0.25 +	9
Weight: 4		

Table 7.3 Ranges and ratings for aquifer media

A – Aquifer Media		
Range	**Rating**	**Typical Rating**
Massive shale	1-3	2
Metamorphic/Igneous	2-5	3
Weathered Metamorphic/Igneous	3-5	4
Glacial Till	4-6	5
Bedded Sandstone, Limestone and Shale Sequences	5-9	6
Massive Sandstone	4-9	6
Massive Limestone	4-9	6
Sand and Gravel	4-9	8
Basalt	2-10	9
Karst Limestone	9-10	10
Weight: 3		

Table 7.4 Ranges and ratings for soil media

S-Soil Media	
Range	**Rating**
Thin or Absent	10
Gravel	10
Sand	9
Peat	8
Shrinking and/or Aggregated Clay	7
Sandy Loam	6
Loam	5
Silty Loam	4
Clay Loam	3
Muck	2
No shrinking and No aggregated clay	1
Weight: 2	

Table 7.5 Ranges and ratings for topography

T-Topography (Percent Slope)	
Range	**Rating**
0-2	10
2-6	9
6-12	5
12-18	3
18+	1
Weight: 1	

Table 7.6 Ranges and ratings for aquifer hydraulic conductivity

C-Hydraulic Conductivity		
Range		**Rating**
gpd/ft^2	**m^{3}pd/m^2**	
1-100	0.041 - 4.1	1
100-300	4.1 - 12.3	2
300-700	12.3 - 28.7	4
700-1000	28.7 - 41.0	6
1000-2000	41.0 - 82.0	8
2000 +	82.0 +	10
Weight: 3		

Table 7.7 Ranges and ratings of the vadose zone media

I-Impact of the Vadose Zone Media		
Range	**Rating**	**Typical Rating**
Confining Layer	1	1
Silt / Clay	2-6	3
Shale	2-5	3
Limestone	2-7	6
Sandstone	4-8	6
Bedded Limestone, Sandstone, Shale	4-8	6
Sand and Gravel with significant Silt and Clay	4-8	6
Metamorphic / Igneous	2-8	4
Sand and Gravel	6-9	8
Basalt	2-10	9
Karst Limestone	8-10	10
Weight: 5		

Twelve aquifers' vulnerability was studied by DRASTIC Index in Oklahoma. As a result of this study; it was found that bedrock aquifers had the lowest DRASTIC indices and were the least vulnerable to contamination from pollutants introduced at the ground surface. The alluvium and terrace aquifers have the highest DRASTIC indices and were the most vulnerable (Osborn, Eckenstein & Koon, 1998).

Groundwater in coastal areas are more vulnerable to pollution (Ertekin, 2004).

7.2 Material and Method

In this study; possible changes that may be occur in the case of irrigation of Menemen Plain with treated wastewater effluent of İzmir Municipal Wastewater Treatment Plant, were tried to be estimated. For this purpose, groundwater's present situation in the plain in Tuzcullu, Musabey, Kesikköy, Günerli, Seyrek Zones is obtained from the results of analysis, which were done by DSİ, and İZSU and vulnerability of the aquifer is determined by DRASTIC Model.

It has been seen that; effluent of wastewater treatment plants cause salt problems in groundwater if it is directly used for irrigation. Because of this, instead of using wastewater directly; using it after diluting in various ratios in certain areas may delay the salt problem.

Chloride concentration is taken into consideration to estimate the salt problem. Treated wastewater's irrigation class according to chloride concentration is defined. Gediz River's chloride concentrations and treated wastewater's chloride concentrations are compared and necessary dilution ratios are calculated to prevent salting of groundwater.

7.3 DRASTIC Index Values for the Groundwater in Menemen Plain

Depth to Water (D): The depth to water is distance, in feet, from the ground surface to the water table. It determines the depth of material through which a contaminant must travel before reaching the aquifer. Thus, the shallower the water depth, the more vulnerable the aquifer is to pollution (Osborne, Eckenstein, Koon, 1998).

Values of depth to water in Menemen Plain are found by subtracting water level heights from soil heights of wells, which are given in Table 7.8. Depth to water in Menemen Plain changes between 16.73 and 96.44 feets (5.10 – 29.40 m.).

Table 7.8 Menemen Plain water height values in October 1998

Well	Soil Height (m)	Water Height (m)	Depth to Water (m)	Depth to Water (ft)
Seyrek	5.80	-12.10	17.90	58.72
Günerli	6.00	-12.50	18.50	60.68
Kesikköy	5.00	-13.00	18.00	59.04
Süzbeyli	2.00	-3.10	5.10	16.73
Tuzcullu	3.70	-6.70	10.40	34.12
Musabey	7.00	-12.40	19.40	63.64
Well 2825	8.00	-15.40	23.40	76.76
Well 19013	11.90	-17.50	29.40	96.44
Well 35/3183	5.60	-12.12	17.72	58.13

Net Recharge (R): The primary source of recharge is precipitation, which infiltrates through the ground surface and percolates to the water table. Net recharge is the total quantity of water per unit area, in inches per year, which reaches the water table. Recharge is the principle vehicle for leaching and transporting contaminants to the water table. More recharge means a greater chance for contaminants to reach to the water table (Osborne, Eckenstein, Koon, 1998).

Abstraction value is higher than recharge value in Menemen Plain and because of this reason net recharge in Menemen Plain is taken as 0 inches.

Aquifer Media (A): Aquifer media refers to the consolidated or unconsolidated rock that serves as an aquifer. Larger grain size and the more fractions or openings within the aquifer means higher permeability, and thus vulnerability, of the aquifer. In unconsolidated aquifers, the rating is based on the amount of primary porosity and secondary porosity along fractures and bedding plans (Osborne, Eckenstein, Koon, 1998).

Almost the whole of Menemen Plain is covered by alluvium and alluvium consists of sand and gravel (Gündüz, O., 2004).

Soil Media (S): Soil media is the upper weathered zone of the earth, which averages a depth of six feet or less from the ground surface. Soil has a significant impact on the amount of recharge that can infiltrate into the ground. In general, the less the clay shrinks and swells and the smaller the grain size of the soil, the less like the contaminants will reach the water table (Osborne, Eckenstein, Koon, 1998).

Soil shows shrinking and aggregated clay property in Menemen Plain (Gündüz, O., 2004).

Topography (T): Topography referees to the slope of the land surface. Topography helps control the likelihood that a pollutant will run off or remain long enough to infiltrate through the ground surface. Where slopes are low, there is little run off, and the potential for pollution is greater. Conversely, where slopes are steep, run off capacity is high and the potential for pollution to groundwater is lower (Osborne, Eckenstein, Koon, 1998).

Slope in alluvial sections of the plain is seen as 4 % in Appendix-5.

Impact of the Vadose Zone (I): The vadose zone is the unsaturated zone above the water table. The texture of the vadose zone determines the time of the travel of the contaminant through it. In surficial aquifers, the ratings for the vadose zone are generally the same as the aquifer media. Sometimes a lower rating is assigned if the aquifer media is overlain by a less permeable layer such as clay (Osborne, Eckenstein, Koon, 1998).

Vadose zone in Menemen Plain consists of sand and gravel (Gündüz, O., 2004).

Hydraulic Conductivity of the Aquifer (C): Hydraulic conductivity referees to the rate at which water flows horizontally through an aquifer. Higher the conductivity means more vulnerable aquifer. The alluvium and terrace aquifers have higher hydraulic conductivity values, ranging from 100 to greater than 2,000 gpd/ft^2 (nearly 81.6 m^3pd / m^2 = 81.6 m/day) (Osborne, Eckenstein, Koon, 1998).

Average hydraulic conductivity of Menemen Plain is 0.79 m/day and this value is equal to 19,37 gpd/ft^2 (Toprak Su Genel Müdürlüğü, 1972).

DRASTIC Values of Menemen Plain are given in Table 7.9.

Table7.9 Vulnerability analysis of Menemen Plain by DRASTIC Index

PLACE	D			R			A			S			T			I			C			DRASTIC NUMBER
	R	**W**	**D.V**	**R**	**W**	**D.V**	**R**	**W**	**D.V**	**R**	**W**	**D.V**	**R**	**W**	**D.V**	**R**	**W**	**D.V**	**R**	**W**	**D.V**	
SEYREK	3	5	15	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**109**
TUZCULLU	5	5	25	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**119**
GÜNERLİ	3	5	15	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**109**
MUSABEY	3	5	15	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**109**
KESİKKÖY	3	5	15	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**109**
SÜZBEYLİ	7	5	35	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**129**
WELL 2825	2	5	10	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**104**
WELL 19013	2	5	10	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**104**
WELL 35/3183	3	5	15	1	4	4	8	3	24	7	2	14	9	1	9	8	5	40	1	3	3	**109**

W: Weight
R:Rate
D.V.: Drastic Value

CHAPTER EIGHT
RESULTS AND DISCUSSIONS

Vulnerability analysis of Menemen Plain by DRASTIC Index is shown in Table 7.9. Average DRASTIC Value is 116.50. This value is in the middle of DRASTIC Index. It means that, the plain is vulnerable for irrigation with treated wastewater.

Vulnerability maps can be prepared according to DRASTIC Index results and these maps can be useful to prevent pollution of groundwater by new activities.

Chloride concentration is taken into consideration to estimate the salt problem. Treated wastewater is fifth class irrigation water, because of having a chloride concentration higher than 710 mg/L (treated wastewater's chloride concentration is 1892, 46 mg/L). Because of this; it is not appropriate to use treated wastewater from IWTP as irrigation water.

Gediz River's chloride concentration and treated wastewater's chloride concentrations are compared and necessary dilution ratios are calculated. Vulnerable zones are determined and alternatives are studied to decrease the negative effects of treated wastewater irrigation to the groundwater quality.

Chloride concentrations in study area are shown in Table 8.1 and Table 8.2.

Table 8.1 Chloride concentrations in Menemen Plain (DSİ and İZSU Drinking Water Analysis, 2000-2004).

Place	Chloride Concentration (mg/L)
Değirmendere	19.88
Seyrek	135.22
Günerli	148.69
Kesikköy	76.72
Menemen Municipality Water Storage and Wells	75.48
Çavuşköy	80.00

Table 8.1 shows average chloride concentrations between 2000 and 2004. In this table; average chloride concentration in Menemen Municipality Water is given as 75.48 mg/L; but when 2004 values are examined from Table 8.2; it can be seen as 95.72 mg/L. This means that; chloride concentration is increasing in the wells or İZSU's drinking water wells' chloride concentration is lower than irrigation water wells' chloride concentration.

Table 8.2 Average chloride, SAR, EC values and irrigation water class of Menemen (DSİ, 2004).

PLACE	AVERAGE Cl (mg/L)	AVERAGE SAR	WATER CLASS	AVERAGE EC (micromho/cm)
Kesikköy	76.72	1.29	C2S1	680.33
Günerli	148.69	1.71	C3S1	932.00
Seyrekköy	135.22	2.47	C3S1	1014.50
Menemen Municipality Storage	95.72	1.46	C3S1	1354.00

Chloride concentration in Menemen Plain groundwater changes between 76.72 and 148.69 mg/L; sodium adsorption rate (SAR) is between 1.29 and 4.47 and electrical conductivity is between 680.33 and 1354.00 micromho/cm. It is second class irrigation water according to electrical conductivity in Kesikköy and third class in Günerli, Seyrekköy and Menemen Municipality. When sodium adsorption rates are examined; it is seen that groundwater is first class irrigation water.

According to DRASTIC Index, alluvium in the plain is vulnerable to pollution. In order to prevent salt problem in these sections; wastewater may be diluted with Gediz River's water before irrigation application.

In a private conversation with İzmir Provincial Environmental and Forest Directorate, it has been mentioned that Gediz River's water was fourth class water according to "Quality Criteria of Inland Water Resources Classification". It is said that chloride concentration was not evaluated; but it can be accepted as 400 mg/L because in Quality Criteria of Inland Water Resources Classification, rivers which contain chloride concentration higher than 400 mg/L are fourth class water. Quality Criteria of Inland Water Resources Classification Table is given in Table 8.3.

Table 8.3 Quality Criteria of Inland Water Resources Classification (Water Pollution Control Regulator, 2004)

	WATER QUALITY CLASS			
WATER QUALITY PARAMETERS	I	II	III	IV
A) Pyhsical and inorganic – chemical Parameters				
1)Temperature (^oC)	25	25	30	> 30
2) pH	6.5-8.5	6.5-8.5	6.0-9.0	Other than 6.0-9.0
3) Dissolved Oxygen (mg O_2/L)[a]	8	6	3	< 3
4) Oksijen saturation (%)[a]	90	70	40	< 40
5) Chloride (mg Cl^-/L)	25	200	400[b]	> 400
6) Sulphate (mg $SO_4^=$/L)	200	200	400	> 400
7) Amonium nitrogen (mg NH_4^+-N/L)	0.2[c]	1[c]	2[c]	> 2
8) Nitrite nitrogen (mg NO_2^--N/L)	0.002	0.01	0.05	> 0.05
9) Nitrate nitrogen (mg NO_3^--N/L)	5	10	20	> 20
10) Total phosphorus (mg P/L)	0.02	0.16	0.65	> 0.65
11) Total Dissolved Material (mg/L)	500	1500	5000	> 5000
12) Colour (Pt-Co unit)	5	50	300	> 300
13) Sodium (mg Na^+/L)	125	125	250	> 250
B) Organic parameters				
1) Chemical Oxygen Demand (KOİ) (mg/L)	25	50	70	> 70
2) Biochemical Oxygen Demand (BOİ) (mg/	4	8	20	> 20
3) Total organic carbon (mg/L)	5	8	12	> 12
4) Total kjeldahl-nitrogen (mg/L)	0.5	1.5	5	> 5
5) Oil and gress (mg/L)	0.02	0.3	0.5	> 0.5
6) Surface active materails which react with methilen blue (MBAS) (mg/L)	0.05	0.2	1	> 1.5
7) Fenolic materials (mg/L)	0.002	0.01	0.1	> 0.1
8) Mineral oils (mg/L)	0.02	0.1	0.5	> 0.5
9) Total pesticides (mg/L)	0.001	0.01	0.1	> 0.1
C) İnorganic pollution parameters[d]				
1) Mercury (µg Hg/L)	0.1	0.5	2	> 2
2) Cadmium (µg Cd/L)	3	5	10	> 10
3) Lead (µg Pb/L)	10	20	50	> 50
4) Arsenic (µg As/L)	20	50	100	> 100
5) Cupper (µg Cu/L)	20	50	200	> 200
6) Chromium (total) (µg Cr/L)	20	50	200	> 200
7) Chromium (µg Cr^{+6}/L)	Too little for measurement	20	50	> 50
8) Cobalt (µg Co/L)	10	20	200	> 200
9) Nickel (µg Ni/L)	20	50	200	> 200
10) Zinc (µg Zn/L)	200	500	2000	> 2000
11) Cyanide (total) (µg CN/L)	10	50	100	> 100
12) Floride (µg F^-/L)	1000	1500	2000	> 2000
13) Free chloride (µg Cl_2/L)	10	10	50	> 50
14) Sulfide (µg $S^=$/L)	2	2	10	> 10
15) Iron (µg Fe/L)	300	1000	5000	> 5000
16) Manganese (µg Mn/L)	100	500	3000	> 3000
17) Boor (µg B/L)	1000[e]	1000[e]	1000[e]	> 1000
18) Celenium (µg Se/L)	10	10	20	> 20
19) Barium (µg Ba/L)	1000	2000	2000	> 2000
20) Alluminum (mg Al/L)	0.3	0.3	1	> 1
21) Radioactivity (pCi/L)				
alfa-activity	1	10	10	> 10
beta-activity	10	100	100	> 100
D) Bacteriologic parameters				
1) Fecal coliform(EMS/100 mL)	10	200	2000	> 2000
2) Total coliform (EMS/100 mL)	100	20000	100000	> 100000

If it is wanted to obtain fourth class irrigation water; this water's chloride concentration must not exceed 710 mg/L.

Gediz River's chloride concentration is accepted as 400 mg/L and treated wastewater's chloride concentration is 1892.46 mg/L. Gediz River's and treated wastewater's mixing ratio to obtain 1 L irrigation water with 710 mg/L chloride is calculated below:

V_1: Treated wastewater's volume

V_2: Gediz River's volume

V_3: Mixed water's volume

C_1: Treated wastewater's chloride concentration

C_2: Gediz River's chloride concentration

C_3: Mixed water's chloride concentration

$V_1 * C_1 + V_2 * C_2 = V_3 * C_3$

$V_1 * 1892.46$ mg/L + $V_2 * 400$ mg / L = 1 L * 710 mg/L

$V_1 + V_2 = 1$ L

⇨ $V_1 = 0.207$ L, $V_2 = 0.793$ L

⇨ Mixed irrigation water must be consist of 20.7 % treated wastewater and 79.3 % of Gediz River. This ratio is the minimum mixing ratio. If less chloride concentration is wanted; Gediz River ratio must increase or treated wastewater ratio must decrease.

Different mixing ratios of Gediz River and treatment plant effluent are calculated for different irrigation water chloride concentrations to obtain the optimum chloride concentration in irrigation. Table 8.4 gives the mixing ratios of treatment plant effluent and Gediz River water for different irrigation water chloride concentrations.

Table 8.4 Mixing ratios of Gediz River and İzmir Municipal Wastewater Treatment Plant effluent

Gediz River Chloride Concentration (mg/L)	Treatment Plant Effluent Chloride Concentration (mg/L)	Treatment Plant Effluent Volume%	Gediz River Volume%	Gediz River &Treatment Plant Effluent Mixture Chloride Concentration (mg/L)
400.00	1892.46	-20.10	120.10	100.00
400.00	1892.46	-13.40	113.40	200.00
400.00	1892.46	-6.70	106.70	300.00
400.00	1892.46	0.00	100.00	400.00
400.00	**1892.46**	**6.70**	**93.30**	**500.00**
400.00	**1892.46**	**13.40**	**86.60**	**600.00**
400.00	**1892.46**	**20.10**	**79.90**	**700.00**
400.00	**1892.46**	**26.80**	**73.20**	**800.00**

It is seen that irrigation water's chloride concentration can not be less than 500 mg/L if Gediz River water's chloride concentration is not less than 400 mg/L.

It is thought that; Gediz River's chloride concentration might be less than 400 mg/L although it is in fourth class in Quality Criteria of Inland Water Resources Classification; because, if only one parameter is in the fourth class, this water is evaluated as fourth class even if all other parameters are in the first class. Because of this, different dilution ratios for different Gediz River chloride concentrations are calculated and given in Table 8.5.

Table 8.5 Dilution Ratios of Gediz River and Treatment Plant Effluent for different chloride concentrations

Gediz River ChlorideConcentration	Treatment Plant Chloride Concentration	Treatment Plant Volume%	Gediz River Volume%	Gediz River &Treatment Plant Effluent Mixture Chloride(Irrigation Water) Concentration
400.00	1892.46	-20.10	120.10	100.00
400.00	1892.46	-13.40	113.40	200.00
400.00	1892.46	-6.70	106.70	300.00
400.00	1892.46	0.00	100.00	400.00
400.00	**1892.46**	**6.70**	**93.30**	**500.00**
400.00	**1892.46**	**13.40**	**86.60**	**600.00**
400.00	**1892.46**	**20.10**	**79.90**	**700.00**
400.00	1892.46	26.80	73.20	800.00
300.00	1892.46	-12.56	112.56	100.00
300.00	1892.46	-6.28	106.28	200.00
300.00	1892.46	0.00	100.00	300.00
300.00	**1892.46**	**6.28**	**93.72**	**400.00**
300.00	**1892.46**	**12.56**	**87.44**	**500.00**
300.00	**1892.46**	**18.84**	**81.16**	**600.00**
300.00	**1892.46**	**25.12**	**74.88**	**700.00**
300.00	1892.46	31.40	68.60	800.00
200.00	1892.46	-5.91	105.91	100.00
200.00	1892.46	0.00	100.00	200.00
200.00	**1892.46**	**5.91**	**94.09**	**300.00**
200.00	**1892.46**	**11.82**	**88.18**	**400.00**
200.00	**1892.46**	**17.73**	**82.27**	**500.00**
200.00	**1892.46**	**23.63**	**76.37**	**600.00**
200.00	**1892.46**	**29.54**	**70.46**	**700.00**
200.00	1892.46	35.45	64.55	800.00
100.00	1892.46	0.00	100.00	100.00
100.00	**1892.46**	**5.58**	**94.42**	**200.00**
100.00	**1892.46**	**11.16**	**88.84**	**300.00**
100.00	**1892.46**	**16.74**	**83.26**	**400.00**
100.00	**1892.46**	**22.32**	**77.68**	**500.00**
100.00	**1892.46**	**27.89**	**72.11**	**600.00**
100.00	**1892.46**	**33.47**	**66.53**	**700.00**
100.00	1892.46	39.05	60.95	800.00
0.00	**1892.46**	**5.28**	**94.72**	**100.00**
0.00	**1892.46**	**10.57**	**89.43**	**200.00**
0.00	**1892.46**	**15.85**	**84.15**	**300.00**
0.00	**1892.46**	**21.14**	**78.86**	**400.00**
0.00	**1892.46**	**26.42**	**73.58**	**500.00**
0.00	**1892.46**	**31.70**	**68.30**	**600.00**
0.00	**1892.46**	**36.99**	**63.01**	**700.00**
0.00	**1892.46**	**42.27**	**57.73**	**800.00**

The following conclusions may be obtained from Table 8.5:

If Gediz River's chloride concentration is 400 mg/L, the least mixing ratio of treatment plant effluent may be 6.70% for irrigation water with 500 mg/L chloride concentration and it may be maximum 20.10 % for irrigation water with 700 mg/L. Irrigation water with chloride concentration less than 500 mg/L can not be obtained by mixing treatment plant effluent having 1892.46 mg/L chloride concentration and Gediz River. The best irrigation water under these conditions (500 mg/L chloride) is fourth class (if obligatory, it may be used).

If Gediz River's chloride concentration is 300 mg/L, irrigation water with 400 mg/L chloride concentration can be obtained by mixing 6.28 % treatment plant effluent and 92.73 % Gediz River. Maximum treatment plant effluent ratio may be 25.12 % for irrigation water with 700 mg/L chloride. Irrigation water with chloride concentration less than 400 mg/L can not be obtained by mixing treatment plant effluent having 1892.46 mg/L chloride concentration and Gediz River. The best irrigation water that can be obtained is third class with 400 mg/L chloride.

If Gediz River's chloride concentration is 200 mg/L, irrigation water with 300 mg/L chloride can be obtained by mixing 5.91 % treatment plant effluent and 94.09 % Gediz River. Maximum treatment plant effluent ratio may be 29.54 % for irrigation water with 700 mg/L chloride. Second class irrigation water can be obtained with mixing ratios 5.58 % treatment plant effluent and 94.42 % Gediz River with 200 mg/L chloride concentration.

If Gediz River's chloride concentration is 100 mg/L, irrigation water with 200 mg/L chloride can be obtained by mixing 5.58 % treatment plant effluent and 94.42 % Gediz River. Maximum treatment plant effluent ratio may be 33.47 % for irrigation water with 700 mg/L chloride.

Even it is thought that Gediz River does not contain any chloride, only 36.99 % of treatment plant effluent may be mixed with Gediz River to obtain irrigation water with 700 mg/L chloride.

CHAPTER 9
RECOMMENDATIONS

Water scarcity around the world is increasing day by day because of rapid population and industrialization. People use water for many purposes, mainly for domestic and industrial purposes. Groundwater is a high quality water and and is an important source to obtain drinking water. It is also used for irrigation.

Today; one of the most popular alternatives is using treated wastewater as irrigation water. Examples of this alternative can be seen in Israel, USA and Tunisia. But if treated wastewater is going to be used as irrigation water, very detailed studies must be done before the application.

Chemical and biological properties of treated wastewater; soil, plant, surface and groundwater properties, aquifer media, hydraulic conductivity, meteorological properties must be examined carefully. If the results of these examinations are positive, then wastewater may be used as irrigation water; but if they are negative, other alternatives must be evaluated.

Effects of treated wastewater on soil and plants depend on physical and chemical properties of soil, salt resistance of the plants, irrigation technique, and amount of irrigation water and period of irrigation.

The most important effect of irrigation with treated wastewater on groundwater quality is salt. Although a portion of salt is hold by soil and plants; salt concentration is a lot higher than groundwater and causes a danger for groundwater in using it as drinking water.

If it is decided to use treated wastewater of IWTP effluent as irrigation water; electrical conductivity, sodium, magnesium, calcium and chloride concentrations of effluent of treatment plant must be controlled regularly. Analysis of treatment plant effluent and opening observation wells can help to determine the risk of this application before reaching to drinking water wells.

There are different irrigation systems and each of them has different advantages and disadvantages. System, which has minimum risk, must be chosen for treated wastewater irrigation. Flow rate, storing volume, amount of irrigation, and time of irrigation must be evaluated within the context of studies.

Treated wastewater should be applied step by step. First step should not include the areas which have drinking water wells but observation wells must be opened to show the effects of treated wastewater in the plain. If necessary precautions can be taken for the dangers which are observed from observation wells; later other steps should be opened for treated wastewater irrigation.

In order to reduce the salt content of wastewater, seawater intrusion in to the pipes must be avoided. This will cause an increase in the quality of wastewater and will help to meet the farmers need for irrigation water.

To avoid from hazards to human health; uncooked vegetables mustn't be produced by treated wastewater irrigation; instead of producing vegetables, producing industrial plants may be considered.

This study shows that effluent of İzmir Municipal Wastewater Treatment Plant is not suitable for irrigation. Dilution may be a short-term solution because of needed dilution ratios. İzmir Municipal Wastewater Treatment Plant's effluent has a high flow rate and this amount of effluent will has to be stored if it is going to be diluted with Gediz River and a high volume of storage building is needed then.

As the long term solution, effluent of treatment plant must be rehabilitated by stopping sea water infiltration into the collecting canals of the plant and industrial foundations which discharge wastewater to the collecting canals must be forced to apply a pre-treatment which decrease the salt concentration of effluent before discharge.

In such a case; disposing alternatives like urban reuse, industrial use, sea discharge, using in aquaculture must be examined. Technologies which consume less water must be preferred. People must be educated about using water economically.

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APPENDICES

Appendix 1: Menemen Hydrogeologic Map (DSİ, 2004)

Appendix 2: Menemen Alluvium Thickness Map (DSİ, 2004)

Appendix 3: Menemen Geologic Map (DSİ, 2004)

Appendix 4: Menemen Soil Characteristics Maps (Topraksu, 1974 - Survey Staff, 1960)

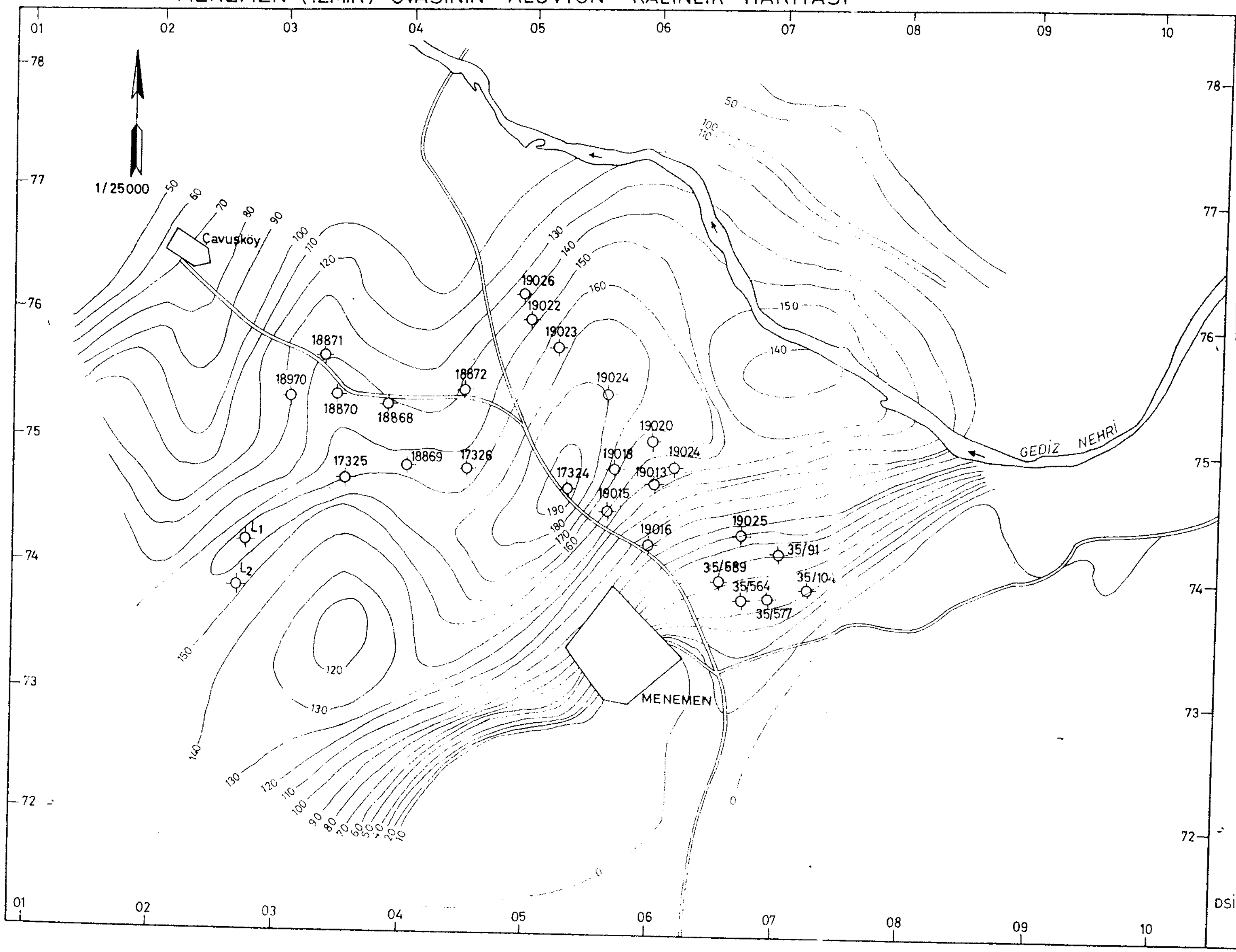
Appendix 5: Menemen General Situation Map (DSİ, 2004)

Appendix 1: Menemen Hydrogeologic Map (DSİ, 2004)

AÇIKLAMALAR
SENOZOYİK
TERSİYER
MİYOSEN
KUVATERNER
OLİGOSEN
MESOZOYİK
KRATASE
YAMANLAR VOLKANİTLERİ
Alüvyon
Yeni alüvyon, eski alüvyon
DOĞRUTEPE FM
ZEYTİNDAĞ FM
Bornova Karmaşığı
Kesit yönü
Doğrultu eğim
Fay, olası fay
Dokanak, olası dokanak
Sürekli akarsu
Mevsimlik akarsu
Kaynak
Bataklık sazlık saha
Sondaj kuyusu
Sulama kanalı
Yol
Demiryolu
Yerleşim alanı
Topoğrafya eğrileri
Tepe
Etüt sahası sınırı
K
1/25000
İZMİR KÖRFEZİ
MENEMEN
MENEMEN OVASI

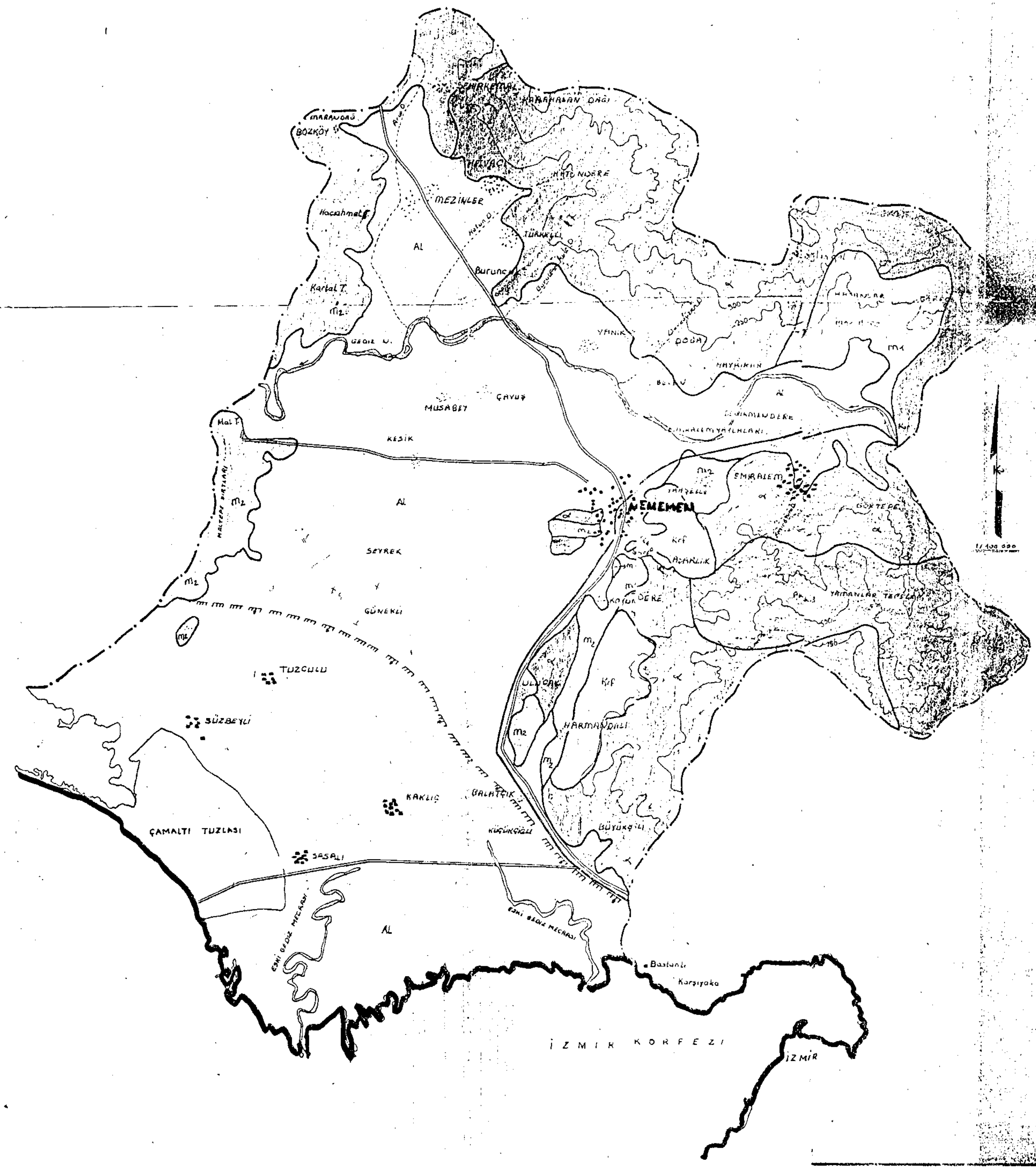
Appendix 2: Menemen Alluvium Thickness Map (DSİ, 2004)

MENEMEN (İZMİR) OVASININ ALÜVYON KALINLIK HARİTASI



EK 6

Appendix 3: Menemen Geologic Map (DSİ, 2004)



İŞARETLER

Perma karbonifer kalker

Krf — Kretase fliş

m_1 — Miosen alt seri kong, marn, kil ve tüf

Miosen, kalker, marn, kil, tüf

Kötü kaliteli yeraltısuyu sınırı EC > 2000

H-1

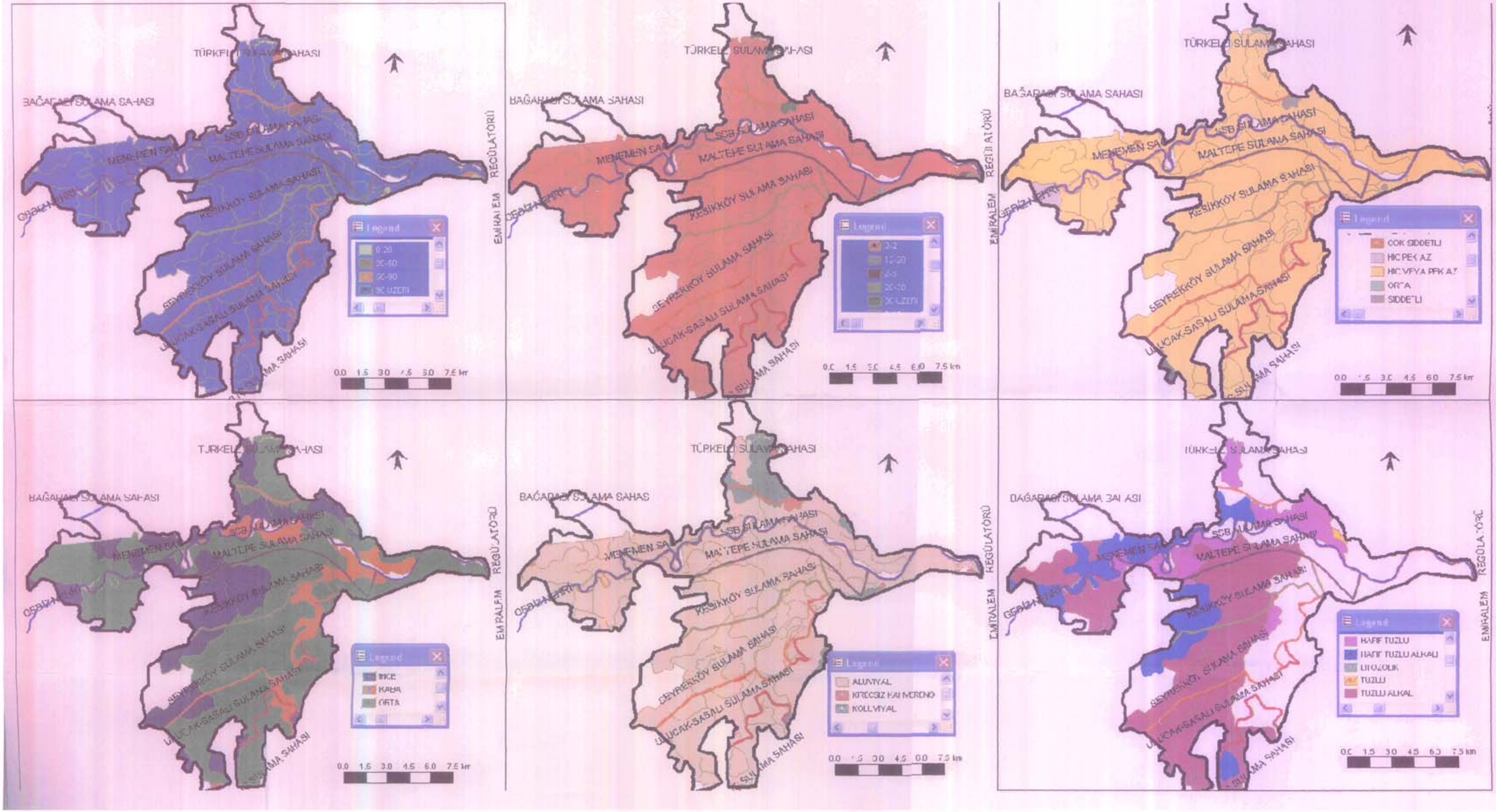
DEVLET SU İŞLERİ GENEL MÜDÜRLÜĞÜ
2. BÖLGE MÜDÜRLÜĞÜ
İZMİR

MENEMEN OVASI

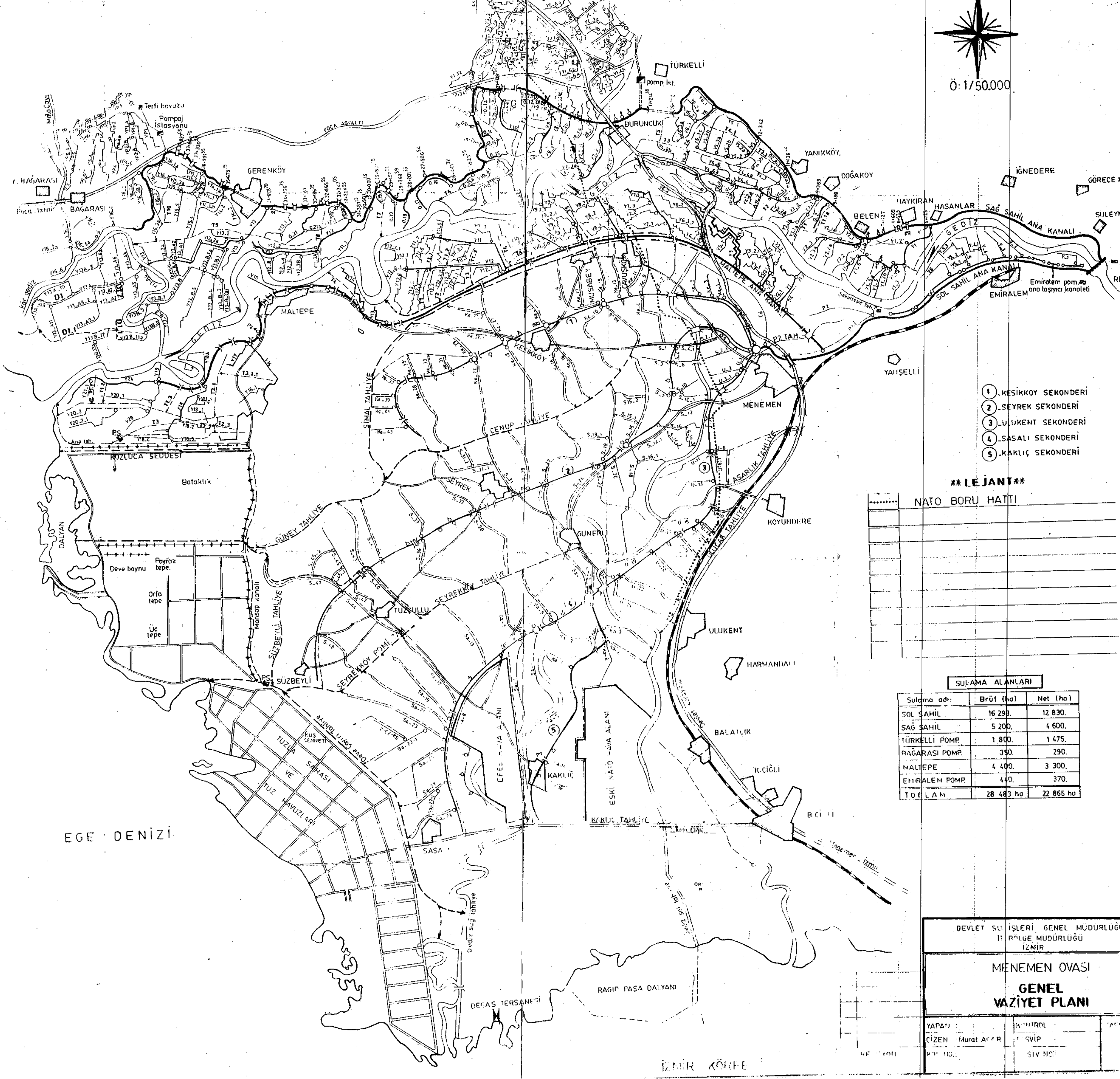
JEOLOJİK HARİTASI

Yapan M. Şakir	Kontrol	Tasdik
Çizen O. GÖKTABAK	Tasvip	
Kod No:	Arşiv No:	
Revizyon		

Appendix 4: Menemen Soil Characteristics Maps
(Topraksu, 1974-Survey Staff, 1960)


TÜRKELİ SULAMA SAHASI
BAĞARASI SULAMA SAHASI
SSB SULAMA SAHASI
MENEMEN SAHASI
MALTEPE SULAMA SAHASI
KESİKKÖY SULAMA SAHASI
SEYREKKÖY SULAMA SAHASI
ULUCAK-SASALI SULAMA SAHASI
GEDİZ NEHRİ
EMİRALEM REGÜLATÖRÜ
Legend
0-20
20-50
50-90
90 ÜZERİ
ÇOK ŞİDDETLİ
HİÇ PEK AZ
HİÇ VEYA PEK AZ
ORTA
ŞİDDETLİ
İNCE
KABA
ORTA
ALUVİYAL
KİREÇSİZ KAHVERENGİ
KOLLUVİYAL
HAFİF TUZLU
HAFİF TUZLU ALKALİ
LİTOZOLİK
TUZLU
TUZLU ALKALİ
0.0 1.5 3.0 4.5 6.0 7.5 km

Appendix 5: Menemen General Situation Map (DSİ, 2004)



1 KESİKKÖY SEKONDERİ
2 SEYREK SEKONDERİ
3 ULUKENT SEKONDERİ
4 SASALI SEKONDERİ
5 KAKLIÇ SEKONDERİ

LEJANT

NATO BORU HATTI

SULAMA ALANLARI

Sulama adı	Brüt (ha)	Net (ha)
SOL SAHİL	16 293.	12 830.
SAĞ SAHİL	5 200.	4 600.
TÜRKELLİ POMP.	1 800.	1 475.
BAĞARASI POMP.	350.	290.
MALTEPE	4 400.	3 300.
EMİRALEM POMP.	440.	370.
TOPLAM	28 483 ha	22 865 ha

DEVLET SU İŞLERİ GENEL MÜDÜRLÜĞÜ
II. BÖLGE MÜDÜRLÜĞÜ
İZMİR

MENEMEN OVASI

GENEL VAZİYET PLANI

YAPAN :	KONTROL :	TASDİK OLUNUR
ÇİZEN : Murat ACAR	T. SVİP	
KONTROL :	SİV NO:	