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Evaluation of Irrigation Water Quality in Gölbaşı District

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ABSTRACT

Gölbaşı district, located at 20 km south of Ankara city is one of the special environmental protection areas (SEPA) of Turkey. The water resources of Golbasi district are under the pressure of urbanization and agricultural activities. In recent years, the demand for groundwater has increased, however accesibility is limited by the quantity and quality of water. This study aims to evaluate the irrigation water quality in Golbasi SEPA. A total of 41 water samples were collected from existing wells and fountains in 11 villages of Golbasi SEPA and analyzed for relevant quality parameters to assess their conformity with irrigation water quality standards. Analysis of samples led to classification of samples into 19 groups with common characteristics. Among them, 20 samples in Group 1-5 had salinity and alkalinity class of C2-S1, and they had the best water quality. On the other hand, 15 samples in Groups 6-14 had salinity and alkalinity class of C3-S1. Since these waters have high level of salt, leaching and special soil tillage is required to avoid salinity problem on the long-term. Yield reduction up to 10-25% may be experienced with alfalfa and corn. Among the samples, only 6 waters had salinity class of C4, and alkalinity of S1, S2 or S4. These waters are not suitable for irrigation under normal conditions. In special cases, they can be used if salt resistant plants are selected, where drainage is good and excess leaching is applied. Land reclamation may be required on the long term. Yield reduction up to 25-50% may be experienced with alfalfa and corn due to salinity.

Keywords: Agriculture; Boron; Golbasi; Salinity; Water quality

Gölbaşı Bölgesi'nde Sulama Suyu Kalitesinin Değerlendirilmesi

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ÖZET

Ankara ilinin 20 km güneyinde yer alan Gölbaşı bölgesi, Türkiye'nin özel çevre koruma bölgelerinden (ÖÇKB) birisidir. Gölbaşı bölgesindeki su kaynakları kentleşme ve tarım faaliyetlerinin baskısı altındadır. Son yıllarda, bölgede yeraltı suyu talebi artmıştır, ancak erişilebilirlik suyun kalitesi ve miktarı ile sınırlıdır. Bu çalışmanın amacı, Gölbaşı ÖÇKB'nde kullanılan sulama suyu kalitesinin değerlendirilmesidir. Gölbaşı ÖÇKB sınırları içinde bulunan 11 mahallede mevcut kuyu ve çeşmelerden 41 adet su örneği toplanmış ve ilgili kalite parametreleri ölçülerek sulama suyu kalite standartlarına uygunluğu değerlendirilmiştir. Örneklerin incelenmesi sonucunda ortak özelliklere sahip 19 grup ortaya çıkmış, bunlardan Grup 1-5 içinde yer alan 20 örneğin tuzluluk ve alkalilik sınıfı C2-S1 olarak bulunmuştur. Bu örnekler, sulama suyu olarak en iyi kaliteye sahip sulardır. Diğer yandan, Grup 6-14 içinde yer alan 15 örneğin tuzluluk ve alkalilik sınıfı C3-S1 olarak bulunmuştur. Bu sular, yüksek tuzluluğa sahip olduklarından uzun dönemde tuzluluk problemi yaratmamak için yıkama ve özel toprak işleme gerekmektedir. Tuzluluk nedeniyle yonca ve mısır gibi bitkilerde % 10-25'e varan verim kaybı gözlenebilir. Örnekler arasında yalnızca 6 örneğin tuzluluk sınıfı C4, alkalilik ise S1, S2 veya S4 olarak bulunmuştur. Bu sular, normal koşullarda sulama suyu olarak kullanılmaya uygun değildir. Özel durumlarda, tuzluluğa dayanıklı bitki türlerinin seçilmesi, drenajın iyi olduğu ve bol yıkama yapılan durumlarda kullanılabilir. Uzun dönemde arazi ıslahı gerekebilir. Tuzluluğa bağlı olarak yonca ve mısırda % 25-50'ye varan oranda verim kaybı gözlenebilir.

Anahtar Kelimeler: Bor; Gölbaşı; Su kalitesi; Tarım; Tuzluluk

1. Introduction

Turkey is under the risk of becoming a water-poor country by 2030 due to limited water resources and expected adverse impacts of population increase and climate change. As a candidate country to the European Union (EU), Turkey has to adopt the environmental policy of EU and transpose the related legislation such as the Water Framework Directive (WFD) (2000/EC/60) (Dalkılıç & Harmancıoğlu 2008). The WFD promotes integrated management of water resources to reduce problems associated with excessive water abstraction, pollution, floods and droughts (EC 2000). Therefore, Turkey has to use her water resources wisely to minimize water stress in the future.

Turkey gets an average of 643 mm precipitation per year, however some regions suffer from water scarcity due to lower precipitation levels. Golbasi district, located at a distance of 20 km south of Ankara city, is one of these regions. It gets an average of 400 mm precipitation per year and has a terrestrial climate. The weather is cold and rainy in winters, whereas it is hot and arid in summers. Annual average temperature is 11.7 °C (DSİ 2007). These conditions result in water scarcity in the region. In addition, water resources are polluted by natural and anthropogenic factors. Although Golbasi has been designated as a Special Environmental Protection Area (SEPA), it is not well protected due to the increasing pressures resulting from urbanization and agricultural activities. These activities adversely affect the quality of surface and groundwater resources in the district. Güngör (2010) reports that the main reason of groundwater pollution in the areas near Eymir and Mogan Lakes is the presence of Hançili geological formation, which results in natural pollution. However, pollution due to anthropogenic factors also threatens the water quality in the district.

Water quality is important for every type of cultivation. When used for irrigation, poor water quality may lead to reduced crop yield and economical losses. Therefore, irrigation water quality should be known in order to maintain long-term productivity. The effects of irrigation water on crop production and soil quality are described by salinity hazard, sodium hazard, pH, alkalinity and specific ions (CSU 2015). However, water salinity, as measured by electrical conductivity (EC) is the most influential water quality guideline on crop productivity. In irrigated agriculture, if salt accumulates in the crop root zone to a certain concentration, a salinity problem occurs, causing yield reduction. The salt originates either from the saline, high water table or the irrigation water (FAO 1994). The usual range of EC for irrigation water is given as 0-3 dS m^{-1} by FAO (1994). This range is divided arbitrarily into three degrees of severity: none, slight to moderate, and severe based on field studies, research trials and observations.

Sodium adsorption ratio (SAR) is used to define sodicity in terms of the relative concentration of sodium compared to the sum of calcium and magnesium ions in water. SAR assesses the potential for infiltration problems due to a sodium imbalance in irrigation water (CSU 2015). The usual range of SAR in irrigation water is given as 0-15 (FAO 1994). SAR values of 1-10 are low and 10-18 are medium. For medium SAR values, amendmends and leaching is required. SAR values of 18-26 are high and they are generally not suitable for continuous use (FAO 1994). Regarding infitration problem, SAR needs to be considered together with EC. This is because the swelling potential of low salinity waters is greater than high salinity waters at the same sodium content. Therefore, a more accurate evaluation of the infiltration/permeability hazard requires using EC together with SAR (CSU 2015).

The residual sodium carbonate (RSC) is important for carbonate-rich and bicarbonate-rich irrigation waters. RSC shows their tendency to precipitate calcium. As RSC increases above zero, sodium hazard to soil structure also increases since water adds more carbonates than divalent cations to the soil. When RSC is positive, calcium is lost from the soil solution. Water resources having RSC greater than 2.5 me L^{-1} cannot be used for irrigation without amendment. However, in general water samples having RSC less than 1.25 me L^{-1} can be used safely for irrigation (FAO 1994). Similarly, water resources containing high salinity (Class C3) and high alkalinity (Class S3) are not suitable for irrigation (USDA 1954).

In Golbasi SEPA, farmers mostly depend on groundwater resources, which are naturally contaminated with boron and salinity. The main reason of salinity is low precipitation and high evaporation in arid and semi-arid regions (Tas & Ozturk 2011). The salt content of irrigation water may adversely affect the yield by reducing the water availability to the crop. In addition, groundwaters in some regions contain high levels of boron as Turkey lands are rich in this element. Although boron is an essential element for plants, it becomes toxic at high concentrations for some plants. Some plants are more sensitive to boron than others. Sensitive plants can tolerate irrigation waters up to 0.3 mg L^{-1} boron, while resistant plants may be able to survive up to 4 mg L^{-1} boron in irrigation water (SKKY 1991; Kabay et al 2007).

Although chloride is essential to plants in very low amounts, it can cause toxicity to sensitive crops at high concentrations. Like sodium, high chloride concentrations cause more problems when applied with sprinkler irrigation. Leaf burn under sprinkler from both sodium and chloride can be reduced by night time irrigation or application on cool, cloudy days (CSU 2015).

In Golbasi SEPA, irrigated agriculture, although limited, is still practiced. Therefore, there is a need to determine the current quality of water resources in the district. For this purpose, the aim of this study is to evaluate the irrigation water quality in Golbasi SEPA. The most widely grown plants in the region, i.e., wheat, barley, alfalfa and corn, were considered for evaluation. Water quality of samples were evaluated in terms of salinity and alkalinity class, effect of salinity on yield, SAR, RSC, boron, chloride and sulfate contents.

2. Material and Methods

2.1. Sampling

In Golbasi SEPA (Figure 1), 11 villages (Ballikpinar, Gaziosmanpasa, Gokcehoyuk, Hacilar, Hacihasan, Karaoglan, Ogulbey, Orencik, Yaglipinar, Yavrucak, Yurtbeyi) were visited during the irrigation season (May-June) in 2012. The area of Gölbaşı SEPA is 274 km^2, which is almost one-third of the area of Golbasi district (738 km^2). It is known that irrigated agriculture is very limited in Golbasi district due to water scarcity. In Golbasi SEPA, the water resources used for irrigation were identified with the help of Golbasi Governorate District Directorate of Food, Agriculture and Livestock. A total of 41 samples were collected from several resources such as wells, lagoons and fountains. In choosing the sampling points, priority was given to the water resources that were already used for irrigation. Among the samples collected, 10 of them were used only for irrigation, 24 of them were used only for livestock breeding, 3 of them were used for both purposes and 4 of them were not used for any purpose. Samples were collected in 1 L polyethylene bottles and immediately sent to the laboratory for analysis.

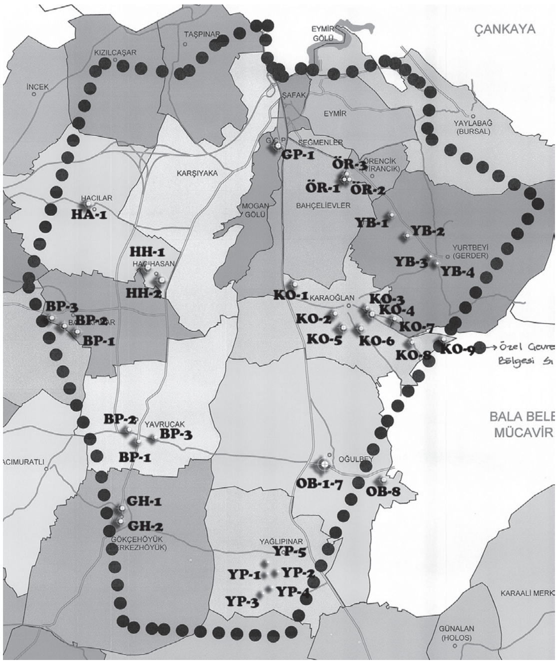

Figure 1- Map of Golbasi SEPA

Şekil 1- Gölbaşı ÖÇKB haritası

Before selecting the sampling points, the chemical analysis results of another study were examined; the study covered 65 samples collected from water resources belonging to private and corporate entities (DSİ 2007). However, after that time, it was found that some of these water resources could not be used or dried out. Therefore, it was possible to collect samples from 41 water resources in this study. Most of the samples belonged to families who deal with irrigated agriculture and livestock breeding. In evaluation of the water quality, the method of irrigation was assumed as sprinkler irrigation.

2.2. Water quality analyses

Water samples were analyzed for electrical conductivity (EC), sodium, calcium, magnesium, carbonate, bicarbonate, boron, chloride and sulfate (Table 1) (Richards 1954; Eltan 1998). Analyses were carried out at the Irrigation Water Quality Analysis Laboratory of Soil Fertilizer and Water Resources Central Research Institute (Ministry of Food Agriculture and Livestock).

Electrical conductivity was measured directly with a Jenway model electrical conductivity meter with temperature correction according to the method TS 9748 EN 27888. Sodium was measured by a flame photometer, where the color of the flame was measured at a wavelength of 589 nm according to the method TS 4530/T1. Calcium and magnesium were measured by titration with EDTA according to the

Table 1- Water quality parameters measured

Çizelge 1- Ölçülen su kalitesi parametreleri

Parameter	*Unit*	*Method*
Electrical conductivity (EC)	µS cm^{-1}	TS 9748 EN 27888
Sodium	me L^{-1}	TS 4530/T1
Calcium	me L^{-1}	TS 8196
Magnesium	me L^{-1}	TS 4474 ISO 6059
Carbonate	me L^{-1}	TS 8489
Bicarbonate	me L^{-1}	TS 8489
Boron	mg L^{-1}	TS 3661
Chloride	me L^{-1}	TS 4164 ISO 9227
Sulfate	me L^{-1}	Barium chloride method

methods TS 8196 and TS 4474 ISO 6059. Carbonate and bicarbonate were measured by titration with sulfuric acid according to the method TS 8489. Boron was measured by the Karmin method using a spectrophotometer according to the method TS 3661. Chloride was measured by Mohr method via titration with silver nitrate according to the method TS 4164 ISO 9227. Sulfate was measured according to barium chloride turbidimetric method.

Sodium adsorption ratio (SAR) was calculated from sodium, calcium and magnesium data. USA Salinity Lab class was determined for each sample by using SAR and electrical conductivity (EC) data. Residual sodium carbonate (RSC) was calculated using carbonate, bicarbonate, calcium and magnesium data.

The quality of water samples were evaluated based on the comparison with guidelines given in Table 2. The values in Table 2 are applicable under normal field conditions prevailing in most irrigated areas in the arid and semi-arid regions of the world (FAO 1994).

In terms of specific ion toxicity, sodium, chloride and boron limits are considered (Table 2) depending on the type of irrigation method. The usual range of use for boron is reported as 0-2 mg L^{-1} and it is 0-30 me L^{-1} for chloride, 0-20 me L^{-1} for sulfate and 6.5-8.4 for pH (FAO 1994).

3. Results and Discussion

The raw data are given in Table 3. As seen, pH of samples changed from 7.0 to 8.7, which is within the normal range of 6.0-8.5, except one sample, that is HA-1 in Hacilar village. This result agrees with previous findings in the district; Maral (2010)

Table 2- Irrigation water quality guidelines (FAO 1985)

Çizelge 2- Sulama suyu kalitesi kılavuz değerleri (FAO 1985)

Potential irrigation problem		*Unit*	*Degree of restriction on use*		
			None	*Slight to moderate*	*Severe*
Salinity (affects crop water availability)					
EC_W		dS m^{-1}	< 0.7	0.7-3.0	> 3.0
Infiltration (affects infiltration rate of water into the soil. Evaluate using ECw and SAR together)					
SAR	0-3	EC_W	> 0.7	0.7-0.2	< 0.2
	3-6		> 1.2	1.2-0.3	< 0.3
	6-12		> 1.9	1.9-0.5	< 0.5
	12-20		> 2.9	2.9-1.3	< 1.3
	20-40		> 5.0	5.0-2.9	< 2.9
Specific ion toxicity (affects sensitive crops)					
Na	Surface	SAR	< 3	3-9	> 9
	Sprinkler	me L^{-1}	< 3	> 3	
Cl	Surface	me L^{-1}	< 4	4-10	> 10
	Sprinkler	me L^{-1}	< 3	> 3	
B		mg L^{-1}	< 0.7	0.7-3.0	> 3.0
Miscellaneous effects (affects susceptible crops)					
Bicarbonate (HCO_3^-)	Overhead sprinkling only	me L^{-1}	< 1.5	1.5-8.5	> 8.5
pH				Normal range 6.5-8.4	

have found that pH of two samples collected in Golbasi are 7.7 and 7.8. Similarly, DSİ (2007) have found that pH of 34 samples collected from wells in Golbasi SEPA villages are 6.6-8.0, with very few samples having pH slightly higher than 8.0.

Electrical conductivity of samples varied between 0.4 dS m^{-1} and 4.0 dS m^{-1} (Table 3). These values are similar to those found by Maral (2010); EC of two samples collected in Golbasi were found as 1.3 dS m^{-1} and 1.9 dS $m^{-1,}$ respectively. Similarly, DSİ (2007) have found that EC of 34 samples changed from 0.3 dS m^{-1} to 4.5 dS m^{-1} in Golbasi SEPA.

US salinity and alkalinity classes of samples collected in Golbasi SEPA were determined. A total of 21 samples (51%) were C2-S1, 14 samples (34%) were C3-S1, and the remaining 6 samples (15%) were C4-S1, C4-S2 and C4-S4 (Table 3). So, only two samples were C4-S4, which are HA-1 and YC-3, respectively. HA-1 (drilling well with 200 m depth) is currently used for landscape irrigation in a school garden in Hacilar village and YC-3 (drilling well with 96 m depth) belongs to a private property in Yavrucak, which can not be not used at the moment. These data agree well with literature findings; Maral (2010) found the salinity class of two samples in Golbasi as C3. Similarly, DSI (2007) found that 16 samples (47%) were C2-S1, 11 samples (32%) were C3-S1, and the remaining 7 samples (21) were C1-S1, C3-S2 and C4-S4. Thefore, both the results of this study and literature findings clearly show that most water resources in Golbasi SEPA have moderate to high salinity and low alkalinity.

The Na^{+} concentration of samples changed from 0.1 me L^{-1} to 26.9 me L^{-1}. The usual range for Na^{+} is 0-40 me L^{-1} (FAO 1994). Therefore, all the samples contain acceptable Na^{+} concentrations. The values of Na^{+} determined by DSİ (2007) are also within the acceptable range. The Ca^{+2} and Mg^{+2} concentrations of 41 samples changed from 0.1 me L^{-1} to 7.1 me L^{-1} and from 0.1 me L^{-1} to 28.9 me L^{-1}, respectively. According to FAO (1994), the usual ranges for Ca^{+2} and Mg^{+2} in irrigation water are 0-20 me L^{-1} and 0-5 me L^{-1}, respectively. Therefore, it can be said that Ca^{+2} content of the samples are acceptable, however Mg^{+2} content of 14 samples (34%) are much higher than the acceptable range (Table 3). In Golbasi district, the origin of Mg^{+2} is the ophiolitic rocks. The surface and shallow waters become rich in Mg^{+2} and bicarbonate while permeating through the ophiolitic rocks and reach the aquifer formations. Therefore, in groundwaters Mg^{+2} content is often dominant as compared to the Ca^{+2} contents.

In magnesium dominated waters, i.e., Ca/Mg is less than 1, the potential effect of sodium may be slightly increased. This means a given SAR value will show slightly more damage if the Ca/Mg ratio is less than 1. The lower the ratio, the more damaging is the SAR (Maral 2010). When determining the suitability of a water for irrigation, there are insufficient data to make the Ca/Mg ratio an evaluation factor. However, if an irrigation water is used that has a Ca/Mg ratio less than 1, a further evaluation is needed. Such waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment (FAO 1994). In this study, Ca/Mg ratio of 23 samples (56%) is less than 1. These are BP-1, BP-2, GH-1, OB-1, OB-2, OB-3, OB-4, OB-5, OB-6, OB-7, OB-8, ÖR-1, ÖR-2, ÖR-3, YP-1, YP-2, YP-3, YP-5, YC-1, YC-2, YC-3, YB-2 and YB-4 (Table 3). According to the comments given in Table 4, further evaluation will be required regarding plant nutrition and addition of calcium as fertilizer or soil amendment in case of using these water resources for irrigation.

In most water samples, there is no carbonate. The carbonate content of only four samples are greater than zero; HA-1, KO-9, YP-3 and YC-3. They are between 0.6-5.2 me L^{-1}, which are higher than the FAO usual range of 0-0.1 me L^{-1}. On the other hand, bicarbonate content of samples is between 3.5-14.2 me L^{-1}, where FAO usual range is given as 0-10 me L^{-1} (1994). Therefore, only four samples have bicarbonate levels higher than FAO usual range; these are GP-1, HA-1, OB-8 and YC-4 (Table 3).

Table 3- Water quality data

Çizelge 3- Su kalitesi verileri

Village/Sample/Source		*pH*	*EC* $(dS\ m^{-1})$	Na^{+1} $(me\ L^{-1})$	Ca^{+2} $(me\ L^{-1})$	Mg^{+2} $(me\ L^{-1})$	*Ca/Mg*	CO_3^{-2} $(me\ L^{-1})$	HCO_3^{-} $(me\ L^{-1})$	*B* $(mg\ L^{-1})$	Cl^{-1} $(me\ L^{-1})$	SO_4^{-2} $(me\ L^{-1})$	*SAR*	*RSC* $(me\ L^{-1})$	*Salinity Class*
Ballikpinar															
BP-1	Fountain	7.75	0.53	0.43	2.03	2.93	0.7	0.00	4.35	0.9	0.33	0.76	0.27	0.00	C2-S1
BP-2	Dug well (12 m)	7.09	3.85	20.30	5.32	12.82	0.4	0.00	8.87	1.9	13.11	16.65	6.71	0.00	C4-S2
BP-3	Drilling well (80 m)	7.40	0.71	1.51	3.73	1.81	2.1	0.00	5.37	0.0	0.85	0.92	0.91	0.00	C2-S1
Gaziosmanpasa															
GP-1	Dug well (7 m)	7.42	1.63	4.40	7.13	5.80	1.2	0.00	10.34	0.7	5.69	1.45	1.73	0.00	C3-S1
Gokcehoyuk															
GH-1	Fountain 1	7.06	0.76	0.88	2.48	4.00	0.6	0.00	6.35	0.4	1.00	0.12	0.49	0.00	C3-S1
GH-2	Fountain 2	7.25	0.71	0.77	3.60	2.94	1.2	0.00	5.54	0.3	0.86	0.97	0.42	0.00	C2-S1
Hacilar															
HA-1	Drilling well (200 m)	8.72	2.36	23.90	0.18	0.13	1.4	4.46	12.21	6.8	6.34	1.23	61.07	16.36	C4-S4
Hacihasan															
HH-1	Dug well (10 m)	7.31	0.99	2.03	4.35	3.86	1.1	0.00	6.00	0.3	1.19	3.11	1.00	0.00	C3-S1
HH-2	Drilling well (80 m)	7.31	1.15	4.55	3.43	3.43	1.0	0.00	6.16	0.6	3.71	1.58	2.45	0.00	C3-S1
Karaoglan															
KO-1	Drilling well (110 m)	8.12	0.78	5.00	1.95	0.94	2.1	0.00	6.13	2.0	1.63	0.17	4.15	3.23	C3-S1
KO-2	Fountain	7.51	0.48	0.51	3.02	1.81	1.7	0.00	4.79	0.4	0.42	0.18	0.33	0.00	C2-S1
KO-3	Drilling well (130 m)	7.50	0.62	1.32	3.64	1.51	2.4	0.00	4.92	0.2	0.61	0.99	0.82	0.00	C2-S1
KO-4	Drilling well (125 m)	7.76	0.48	1.35	3.02	0.72	4.2	0.00	4.41	0.1	0.56	0.19	0.99	0.65	C2-S1
KO-5	Fountain	7.39	0.71	0.86	4.49	2.68	1.7	0.00	6.70	0.1	0.69	0.72	0.45	0.00	C2-S1
KO-6	Drilling well (110 m)	7.54	0.60	1.02	3.78	1.64	2.3	0.00	5.33	0.2	0.71	0.49	0.62	0.00	C2-S1
KO-7	Drilling well	7.93	0.64	3.45	1.89	1.17	1.6	0.00	5.90	0.9	0.62	0.09	2.78	2.82	C2-S1
KO-8	Drilling well	7.41	0.52	0.58	3.52	1.37	2.6	0.00	5.06	0.2	0.44	0.05	0.37	0.16	C2-S1
KO-9	Lagoon 2	8.39	0.44	0.33	3.24	1.26	2.6	0.63	3.52	0.0	0.30	0.43	0.22	0.00	C2-S1

Table 3- (Continued) Water quality data

Çizelge 3- (Devam) Su kalitesi verileri

Ogulbey															
OB-1	Drilling well (125 m)	7.90	1.27	2.49	1.48	9.12	0.2	0.00	7.56	0.8	2.72	3.00	1.08	0.00	C3-S1
OB-2	Drilling well (45 m)	7.90	3.20	2.60	3.66	28.87	0.1	0.00	7.15	0.0	10.74	17.70	0.64	0.00	C4-S1
OB-3	Drilling well (170 m)	7.89	0.72	0.74	0.59	6.02	0.1	0.00	4.64	0.0	1.22	1.60	0.40	0.00	C2-S1
OB-4	Old network	7.91	0.47	0.91	0.84	3.66	0.2	0.00	4.95	0.0	0.45	0.10	0.60	0.41	C2-S1
OB-5	Drilling well (110 m)	7.89	1.22	1.78	1.89	9.79	0.2	0.00	7.39	0.1	2.32	3.93	0.73	0.00	C3-S1
OB-6	Drilling well (120 m)	7.39	3.18	8.90	6.89	15.70	0.4	0.00	5.15	0.1	10.20	16.49	2.64	0.00	C4-S1
OB-7	Fountain	7.73	1.12	1.35	0.77	9.31	0.1	0.00	4.80	0.0	2.77	4.10	0.60	0.00	C3-S1
OB-8	Drilling well (75 m)	7.77	1.45	2.45	4.05	10.32	0.4	0.00	12.74	0.0	1.57	2.73	0.91	0.00	C3-S1
Orencik															
ÖR-1	Old network 1	7.58	0.64	0.45	2.73	4.05	0.7	0.00	5.99	0.0	0.66	0.64	0.24	0.00	C2-S1
ÖR-2	Old network 2	7.79	0.64	0.91	2.87	3.77	0.8	0.00	5.60	0.4	0.46	1.04	0.52	0.00	C2-S1
ÖR-3	Dug well (5 m)	7.07	1.32	2.55	4.51	5.51	0.8	0.00	8.64	0.2	1.85	3.32	1.14	0.00	C3-S1
Yaglipinar															
YP-1	Drilling well (72 m)	7.65	0.79	1.78	2.23	4.77	0.5	0.00	6.21	0.3	1.00	1.66	0.95	0.00	C3-S1
YP-2	Old network	7.91	1.45	5.10	2.48	8.54	0.3	0.00	9.49	0.5	2.37	4.42	2.16	0.00	C3-S1
YP-3	Creek	8.28	2.79	17.40	3.09	10.17	0.3	2.46	7.29	0.4	7.01	14.23	6.73	0.00	C4-S2
YP-4	Fountain 1	7.52	4.64	1.13	1.94	1.49	1.3	0.00	4.39	0.1	0.35	0.00	0.86	0.93	C2-S1
YP-5	Fountain 2	7.43	1.09	4.00	1.86	6.45	0.3	0.00	6.75	0.4	0.86	4.88	1.96	0.00	C3-S1
Yavrucak															
YC-1	Dug well (12 m)	7.18	2.05	8.60	3.53	8.12	0.4	0.00	6.42	1.1	8.65	5.37	3.55	0.00	C3-S1
YC-2	Old network	7.56	0.58	0.69	1.43	3.61	0.4	0.00	4.95	0.3	0.51	0.33	0.43	0.00	C2-S1
YC-3	Drilling well (96 m)	8.43	2.64	26.90	0.13	0.24	0.5	5.16	14.21	9.7	6.81	1.15	62.48	19.0	C4-S4
Yurtbeyi															
YB-1	Drilling well (50 m)	7.09	0.82	1.13	4.30	3.39	1.3	0.00	7.87	0.4	0.89	0.21	0.57	0.13	C2-S1
YB-2	Fountain 1	7.91	0.65	1.02	2.71	3.43	0.8	0.00	6.15	0.4	0.45	0.66	0.58	0.00	C2-S1
YB-3	Old network	7.41	0.45	0.14	3.84	0.76	5.0	0.00	4.33	0.4	0.26	0.17	0.09	0.00	C2-S1
YB-4	Fountain 2	7.67	0.40	0.51	1.57	2.07	0.8	0.00	3.81	0.0	0.40	0.04	0.38	0.14	C2-S1

On the other hand, bicarbonate contents of BP-2, ÖR-3 and YP-2 are very close to the upper limit of 10 me L^{-1}. Similarly, Maral (2010) have found that bicarbonate content of two samples collected in Golbasi were 6-13 me L^{-1}. In addition, DSI (2007) reports bicarbonate levels within 1.7-12.2. These data show that bicarbonate levels of samples analyzed in this study agree with literature.

According to FAO (1994), when using overhead sprinklers, there is no restiction on use of waters having HCO_3^- less than 1.5 me L^{-1}, but there is slight to moderate restriction on use of waters having HCO_3^- of 1.5-8.5 me L^{-1}, and severe restriction for HCO_3^- greater than 8.5 me L^{-1} (Table 1). Therefore, there is slight to moderate restriction on use of 34 water samples (83%), and severe restriction is required for 7 samples (17%) in case of using overhead sprinklers (Table 3 and Table 4).

RSC is zero for 31 samples and above the upper limit of 2.5 me L^{-1} for four samples, namely HA-1, KO-1, KO-7 and YC-3 (Table 3). These water samples cannot be used for irrigation under normal conditions. On the other hand, RSC is below the lower limit of 1.25 me L^{-1} for six samples, namely KO-4, KO-8, OB-4, YP-4, YB-1 and YB-4 (Table 3). Although RSC method had been used to evaluate potential infiltration problems, SAR is the most commonly used recent method (FAO 1994). SAR is within the usual range of 0-15 for all samples except HA-1 and YC-3, which are as high as 61-63. SAR and EC were evaluated together to assess the possible infiltration problems. The SAR of 35 samples (85%) are between 0-3, SAR of 2 samples are between 3-6, and that of 2 samples are between 6-12 (Table 3). There is no restriction on use of these 39 samples in terms of their EC contents. However, for 2 samples having SAR of 61-63, namely HA-1 and YC-3, there is severe restriction (Table 4).

In terms of specific ion toxicity, sodium, chloride and boron contents of samples were evaluated. The boron concentrations in the groundwaters of Golbasi district is of natural origin. For three samples; HA-1, KO-1 and YC-3, boron concentrations were higher than the usual range of 0-2 mg L^{-1}. In addition, boron concentration of BP-2 (1.9 mg L^{-1}) is very close to the upper limit. Boron contents of samples were evaluated regarding four plants that are commonly cultivated in Golbasi district, namely barley, wheat, alfalfa and corn. According to FAO (1994), barley and wheat are sensitive to boron; the acceptable range is 0.75-1 mg L^{-1}. Corn is moderately tolerant to boron; the acceptable range is 2-4 mg L^{-1}. On the other hand, alfalfa is tolerant to boron; the acceptable range is 4-6 mg L^{-1}. Therefore, BP-2 and YC-1 are not suitable for barley and wheat, whereas HA-1 and YC-3 are not suitable for any type of plant considered (Table 4). On the other hand, the remaining 37 samples (90%) are suitable for all types of plants considered in this study. These data are similar to those reported by Maral (2010) and DSI (2007); 82% of samples collected in Golbasi district had boron concentrations in the acceptable range of 0-2 mg L^{-1}. According to these results, boron does not seem to be a significant problem for irrigation, however it should be noted that most of the samples were collected from existing wells, which were probably drilled to the depth of safe boron limits.

Low amounts of chloride is essential for plants however it can be toxic to sensitive plants at high concentrations. When used with sprinkler irrigation, high chloride levels may cause more problems such as leaf burn (Maral 2010). Night time irrigation can be adopted to reduce this problem. The usual range for chloride is 0-30 me L^{-1} (FAO 1994). Wheat, alfalfa and corn are classified as moderately tolerant, whose leaves may show injury at chloride concentrations higher than 3.9 me L^{-1}. Barley is classified as tolerant, for which the lower limit of chloride for showing injury is 9.9 me L^{-1}. Another consideration with chloride is the type of irrigation; for sprinkler irrigation there is no restriction on use of waters having Cl^- concentration less than 3 me L^{-1} and there is slight to moderate restriction above this value. Based on these criteria, evaluation of results showed that Cl^- levels of all water samples are within the usual range set by FAO (1994). A total of 33 samples (80%) have Cl^- concentrations less than 3.9 me L^{-1}; which is the safe level for

Table 4- Evaluation of irrigation water quality

Çizelge 4- Sulama suyu kalite değerlendirmesi

Group	*Sample*	*Evaluation*
1	BP-3 GH-2 KO-5	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. They can be used for every type of plant and soil condition without any hazard.
2	KO-2, KO-3 KO-4, KO-6 KO-8, KO-9 YP-4, YB-3	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation.
3	OB-3 YC-2	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment.
4	BP-1, OB-4 ÖR-1, ÖR-2 YB-2, YB-4	These water resources can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, these water resources can be used for every type of plant and soil condition without any hazard. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation.
5	KO-7	This water resource can be used safely for irrigation of plants that are moderately sensitive to salinity (alfalfa, corn). However, leaching is required for those plants that are sensitive to salinity. In terms of Na^+ contents, this water resource can be used for every type of plant and soil condition without any hazard. When SAR and EC are considered together, there is slight to moderate restriction on the use of this water for irrigation. It is not suitable for use in terms of RSC.
6	HH-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity.
7	GH-1 OB-7 YP-1 YP-5	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and they should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment.
8	YB-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. When SAR and EC are considered together, there is severe restriction on use of this water for irrigation.

Table 4- (Continued) Evaluation of irrigation water quality

Çizelge 4- (Devam) Sulama suyu kalite değerlendirmesi

9	GP-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. A yield reduction of up to 10% can be observed for alfalfa and corn due to salinity. When sprinkler irrigation is used, there is slight or moderate restriction for the use of this water resource. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
10	HH-2	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. A yield reduction of up to 10% can be observed for corn due to salinity. When sprinkler irrigation is used, there is slight or moderate restriction for the use of this water resource.
11	KO-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. When SAR and EC are considered together, there is slight to moderate restriction on use of these waters for irrigation. It is not suitable for use in terms of RSC.
12	OB-1 OB-5 ÖR-3	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and these waters should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% can be observed for corn due to salinity.
13	OB-8 YP-2	These water resources contain high level of salt. If they are used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as barley) and these waters should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% can be observed for alfalfa and corn due to salinity. There is severe restriction on use of these waters by overhead sprinklers due to their high bicarbonate content.
14	YC-1	This water resource contains high level of salt. If it is used continuously, it is required to apply leaching and special soil tillage in order to avoid salinity problem. The plants should be tolerant to salinity (such as salt resistant barley varieties) and this water should not be used if drainage is not adequate. Leaching is required for plants that are sensitive to salinity. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 10% and 25% can be observed for alfalfa and corn, respectively, due to salinity. It is not suitable for plants (wheat, barley) that are sensitive to boron. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.

Table 4- (Continued) Evaluation of irrigation water quality

Çizelge 4- (Devam) Sulama suyu kalite değerlendirmesi

15	OB-2, OB-6	These water resources are not suitable for irrigation under normal conditions. They can be used only under very special conditions. For example, they can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.
16	YP-3	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. It can be used for oragnic soils having coarse textured and high permeability. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury.
17	BP-2	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (salt resistant barley varieties) in areas with good drainage and when excess leaching water is used. It can be used for organic soils having coarse textured and high permeability. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 50% can be observed for alfalfa and corn due to salinity. Plants that are moderately tolerant and tolerant to chloride (alfalfa, corn, wheat, barley) may show injury. It is not suitable for plants that are sensitive to boron (wheat and barley). There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
18	HA-1	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (barley) in areas with good drainage and when excess leaching water is used. It can be used with the condition that leaching and chemical soil improvement are applied for soils having low salt content and high soluble Ca^{+2} content. Land reclamation may be required on the long term. A yield reduction of up to 25% can be observed for alfalfa and corn due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. It is not suitable for plants that are sensitive, moderately tolerant and tolerant to boron (wheat, barley, alfalfa, corn). When SAR and EC are considered together, there is severe restriction on use of this water for irrigation. It is not suitable for use in terms of RSC. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.
19	YC-3	This water resource is not suitable for irrigation under normal conditions. It can be used only under very special conditions. For example, it can be used for plants that are tolerant to salinity (barley) in areas with good drainage and when excess leaching water is used. It can be used with the condition that leaching and chemical soil improvement are applied for soils having low salt content and high soluble Ca^{+2} content. Land reclamation may be required on the long term. Ca/Mg ratio is less than 1, therefore further evaluation is needed. These waters may pose a potential problem related to plant nutrition. An evaluation may be needed to determine if a readily available source of soluble calcium exists in the soil or whether further studies are needed to determine if calcium should be added as a fertilizer or soil amendment. A yield reduction of up to 25% and 50% can be observed for alfalfa and corn, respectively, due to salinity. Plants that are moderately tolerant to chloride (alfalfa, corn, wheat) may show injury. It is not suitable for plants that are sensitive, moderately tolerant and tolerant to boron (wheat, barley, alfalfa, corn). When SAR and EC are considered together, there is moderate restriction on use of this water for irrigation. It is not suitable for use in terms of RSC. There is severe restriction on use of this water by overhead sprinklers due to its high bicarbonate content.

alfalfa, corn and wheat. However, there is slight to moderate restriction on use of GP-1, HA-1, YP-3, YC-1 and YC-3 regarding irrigation of alfalfa, corn and wheat with sprinklers. The use of HH-2 have no restriction for plant types but there is restriction for sprinkler irrigation. On the other hand, there is slight to moderate restriction on use of BP-2, OB-2 and OB-6 for all type of plants considered in addition to sprinkler irrigation (Table 3 and Table 4). Similarly, Maral (2010) and DSİ (2007) have found that chloride content of water resources in Golbasi district are all in the usual range of 0-30 me L^{-1}.

The sulfate ion in irrigation water has fertility benefits. It is also a major contributor to salinity in many irrigation waters. The sulfate concentrations were within the usual range of 0-20 me L^{-1} for all samples analyzed (Table 3). The literature findings were also similar (DSİ 2007; Maral 2010). Therefore, it can be stated that Golbasi SEPA waters have enough sulfate levels.

According to the evaluation of all results, 41 samples were classifed into 19 groups based on their common characteristics, in the order of increasing problematic issues (Table 4). It was found that 20 samples (49%) in Groups 1-5 can be used safely for irrigation of alfalfa and corn, which are moderately sensitive to salinity. Three samples (BP-3, GH-2 and KO-5) in Group 1 can be used without any restriction. Eight samples in Group 2 (KO-2, KO-3, KO-4, KO-6, KO-8, KO-9, YP-4 and YB-3) can also be used safely for irrigation of these plants. However, there is slight to moderate restriction on use of these waters in terms of SAR and EC contents. Two samples (OB-2 and YC-2) in Group 3 have the same evaluation as Group 2, however further evaluation is needed regarding Ca/Mg ratio, which is less than 1. Detailed explanation about the possible further evaluations is given in Table 4. In Group 4, there are 6 samples (BP-1, OB-4, ÖR-1, ÖR-2, YB-2, YB-4) having basically similar characteristics with Group 3, but in addition, there is slight to moderate restriction for these waters in terms of SAR and EC. In Group 5, there is one sample (KO-7), which can be used as the samples in Groups 1-4 but KO-7 is not suitable for use in terms of RSC.

In Groups 6-14, 15 water samples (GP-1, GH-1, HH-1, HH-2, KO-1, OB-1, OB-5, OB-7, OB-8, ÖR-3, YP-1, YP-2, YP-5, YB-1 and YC-1), corresponding to 36% of all samples have high level of salt. If these waters are used continously, leaching and special soil tillage is required to avoid salinity problems. Yield reduction up to 10-25% may be observed for alfalfa and corn due to salinity. Specific reduction percentages for each group of samples are given in Table 4.

In Groups 15-19, six waters (BP-2, HA-1, OB-2, OB-6, YP-3, YC-3), which correspond to 15% of all samples, are not suitable for irrigation under normal conditions. They can be used under very special conditions such as selection of plants that are tolerant to salinity (such as salt resistant barley varities) in areas with good drainage, and application of excess leaching. Land reclamation may be required on the long-terms if these waters are used. Yield reduction up to 25-50% may be observed due to salinity. Chloride may be harmful for the leaves of moderately tolerant plants such as alfalfa, corn and wheat. The water sample BP-2 in Group 17 is not suitable for plants that are sensitive to boron (wheat and barley). Water samples HA-1 and YC-3 in Groups 18-19 are not suitable even for plants that are tolerant to boron (such as alfalfa).

4. Conclusions

This study figures out the existing situation in terms of water quality used for agriculture in Golbasi SEPA. The analysis of samples taken from 41 points revealed that almost half of the samples are suitable for irrigation, almost one-third of samples contain high levels of salt and need proper management to avoid salinity problems. Less than one-fifth of samples are not suitable for irrigation under normal conditions. Further research is required to determine the specific land reclamation requirements.

Golbasi Special Environmental Area is suffering from water scarcity and water quality problems. In recent years, there has been an increasing demand for groundwater resources for irrigation. Indeed, drilling new wells is not allowed anymore in an attempt to protect the groundwater resources in the region. Salinity problems may adversely affect the agricultural activities in terms of finding suitable water resources for irrigation. It is suggested to switch to alternative water resources such as wastewater reuse and rainwater harvesting in order to minimize water extraction from groundwater resources.

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