INVESTIGATION AND MODELLING OF WATER QUALITY OF GÖKSU RIVER (CLEADNOS) IN AN INTERNATIONAL PROTECTED AREA BY USING GIS

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Abstract: Göksu Delta is an important wetland where the Göksu River reaches to sea in the eastern of the town Taşucu-Içel. The delta is classified as a Wetland of International Importance according to the Ramsar Convention on Wetlands of International Importance. The amount of fertilizers used in this area was 7200 tons in 2006. These pollutants affect the surface and groundwater quality negatively. The intensively used fertilizers and pesticides contain not only N- and P compounds but also some heavy metals. The contents of all pollutants in surface waters were determined for four different seasons between 2006 and 2008 and with these data a Geographic Information System (GIS) has been constructed by using Map Info. From the photometric heavy metal analysis, it is inferred that the excess concentration of Fe, Ni, Mn, Mo and Cu at some locations is the cause of undesirable quality for drinking purposes. The source of excess concentration of various heavy metals is the agricultural activities and fertilizers. It is determined that in all periods between 2006 and 2008 the heavy metals and other pollutants in the fertilizers and pesticides transported easily to river water with irrigation return flow. The organic pollutants, including COD, BOD, NH_3 and NO_3 followed the sharply increasing trends from Silifke city to Mediterranean Sea. The water quality of Göksu River is modeled and determined that the waste water discharge of 10700 m^3/day from Silifke city does not create a serious problem because of the high amount of flow rate of Göksu River.

Keywords
Göksu Delta, Göksu River, water pollution, modeling, GIS

1. INTRODUCTION

The Göksu River (Cleadnos) originates in the Taurus Mountains, with a cover area of 10000 km^2 and total length of nearly 250 km. The Göksu Delta is formed by Goksu River near the Southern part of Silifke town in the Mediterranean region, Turkey. The delta is an important wetland (15000 ha) where the Göksu River reaches to sea in the eastern of the town Tasucu-Ice1 (Ayas et al., 1997). There are two aquatic ecosystems in Göksu Delta; Paradeniz Lake and Akgöl Lagoon. Paradeniz has higher salinity than Akgöl, since it is influenced directly by the exchange of sea water.

Göksu Delta is an internationally important wetland due to its location being on a bird migration route. The Environmental Protection Department of the Ministry of Environment has declared the Goksu Delta as a Special Environmental Protection Zone to protect the area against pollution and exploitation, and to ensure that natural resources and cultural assets have a future. The delta is classified as a Wetland of International Importance according to the Ramsar Convention on Wetlands of International Importance. The Goksu Delta has also a special significance for being one of the few remaining areas in the world where sea turtles (Caretta caretta, Chelonia mydas) and blue crabs (Callinectes sapidus) lay their eggs (Glen et al. 1996; Ayas et al. 1997).

The Mediterranean coastline stretching from the city of Silifke to the Susanoğlu region is heavily populated with recent (last 15 years) urban developments (e.g., villas, apartment complexes, and multi-store buildings), which are mostly occupied during summer season for vacation purposes. Due to an increased population influx from the surrounding cities, especially during the peak season (May to September); the population of this region increases several folds (e.g., 2–4 times). As the urbanization process continues, water pollution problems have become increasingly evident, and have led to serious ecological and environmental problems (Jinzhu Maa et al., 1009) The Göksu Delta is not only an urban area but it is also surrounded by densely cultivated orchards (mostly citrus), traditional vegetable farms and greenhouse cultivations, where farming activities continue all year long due to favorable climate. The north of the lakes and eastern part of delta consist of farmland where rice, cotton and peanuts are grown all year.

In the Göksu Delta area, urban and agricultural expansions have caused an ever-growing need for fresh water. Population dynamics and agricultural activities in this region have important implications from the surface water chemistry standpoint, especially in the near-shore area, for farmers who rely upon river waters directly for their irrigation. Because the most widespread land use pattern is agriculture in the delta, agricultural inputs caused high levels of contamination within the lagoons of Goksu Delta and river water. Fertilizers and pesticides are used intensively to increase crop yields. Surface water from Göksu River is utilized for irrigation. Most of the irrigation returns flow in the drainage canals discharges back into the Göksu River and transport some pollutant together to this water system. Beside these pollution sources, manure and urban areas with their cesspools are other pollution sources for surface and ground waters in Göksu Delta.

In the previous studies, data showed that about 94 tons of pesticides and 520 kg/ha of mineral fertilizers were used within a year at Göksu Delta (Çetinkaya, 1996). Ayas et al. (1997) reported that various environments and organisms were contaminated by 13 different pesticides and their residues. It was determined that the use of pesticide in Mediterranean region is more than average consumption of Turkey (Dalen et al., 2005). Erdoğan and Karaca (2001) reported that this level was 9.9 kg per ha and 102 different types of pesticides were used in agriculture areas in Göksu Delta. The amount of fertilizers was 7200 tons in 2006. The intensively used fertilizers and pesticides contain not only N- and P compounds but also some heavy metals. These pollutants affect the surface and groundwater quality negatively. The Göksu River has recently been the focus of attention due to recognition of the increasing stress being placed on its water resources and of the resulting environmental degradation in the Göksu delta. Based on surveys and chemical analyses, the surface water qualities in the Göksu Delta were investigated, in order to understand the sources of water pollution and the evolution of water quality in Göksu River.

GIS is an effective tool for storing large volumes of data that can be correlated spatially and retrieved for the spatial analysis and integration to produce the desirable output. GIS has been used by scientists of various disciplines for spatial queries, analysis and integration for the last three decades (Burrough and McDonnell, 1998).The purpose of this study is to understand the pollution of river water with photometric measurements in the basin and modelling and to represent it pictorially using the geographic information system (GIS).

2. Site description

The Göksu Delta is situated in the Mediterranean Sea region of the southeastern part of Turkey and extends from 36^o15 –36^o25 of latitude north to 33^o55-34^o05 of longitude west. The Göksu Delta area is bounded by the Taurus Mountains on the northern side and by the Mediterranean Sea on the southern side. The southern portion of the Göksu Delta area is a delta plain made up of sediments from Göksu River. The Goksu River flow regime is also strongly dependent on the seasonal rains and temperature. Average flow of Goksu River is 130 m^3/s where it reaches the highest value during May. Topographic structure in the north of the investigated area (Taurus Mountains) is rugged with altitudes ranging from 300 to 1,500 m.

In the Göksu Delta area, climate is characterized by hot and dry periods in summer and by warm and wet periods in winter, which is typical for the coastal zones around the Mediterranean Sea. The mean annual temperature in this area is 19^oC. Showers start in October, and continue till mid April and the maximum rainfall occurs in December. The Göksu Delta area receives slightly higher than 607 mm of precipitation annually, and extended periods (i.e., 3–4 months) without precipitation are common

The geological map obtained from the MTA (General Directorate of Mineral Research and Exploration) is used as the basis for this study. The map was updated and the sampling points were interpreted through digital processing.

The oldest rock unit of the Göksu Delta is Akdere Formation of Paleozoic Age, which consists of marble, schist and quarzite. Akdere Formation (middle-upper devonian) is generally found in the northern part of the study area (Fig. 1). Akdere Formation contains various rocks with differing compositions including sandstone, siltstone, dolomite and limestone. Kusyuvası Formation (Middle trias) consists of limestone. Tokmar Formation (upper jura-lower cretaseous) is found in the western part of delta and contains dolomite and limestone.Tertiary units are composed of oligo-miocene Gildirli formation, lower-middle miocene Karaisali formation and middle-upper miocene Kuzgun formation. (Fig.1). Tertiary rocks consist of a succession of marine, lacustrine, and fluvial deposits, which display transitional characteristics both vertically and areally in the study area.

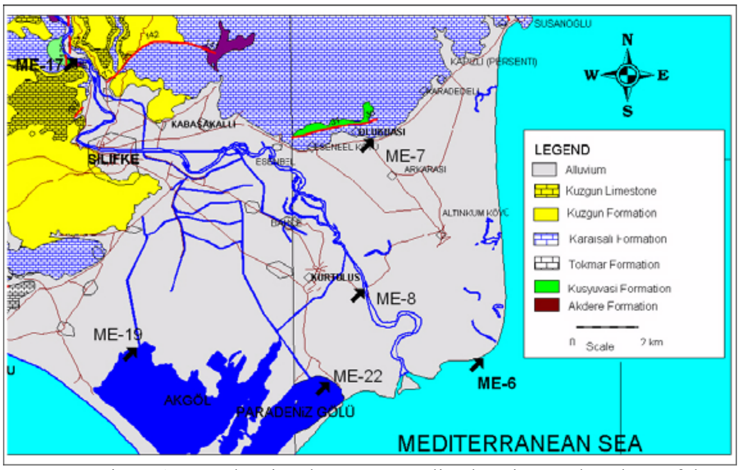

Figure 1. Map showing the water sampling locations and geology of the study area

The Quaternary basin-fill deposits are a heterogeneous mixture of metamorphic and sedimentary rock detritus ranging from clay to boulder size. The mixture includes stream alluvium, stream-terrace deposits, fan deposits, delta deposits, shore deposits. The basin-fill deposits vary greatly in lithology and grain-size, both vertically and areally. Accordingly, the hydraulic properties of these deposits can differ greatly over short distances, both laterally and vertically. The alluvial aquifer consists of a heterogeneous mixture of gravel, sand, silt, clay and sandy-clay. Conceptually the aquifer system in the delta is an unconfined aquifer

3. Materials and methods

For chemical analysis, a total of 6 water samples from the surface waters in Göksu Delta were obtained during 2006-2008 by four separate sampling campaigns at the sampling points shown in Fig. 1. Field work took place between 2006 and 2008, and surface water samples were collected from the Göksu delta. At the same period the contents of all pollutants are determined for four different seasons and with these data a Geographic Information System (GIS) is constructed by using Map Info. Table 1 summarizes the chemical analysis results for water samples collected from the Göksu Delta.

Table 1: Results of chemical analyses of the water samples from four separate sampling campaigns between 2006 and 2008. Concentrations are in milligram per liter

	ME-17 Göksu				ME-19 Akgöl				ME-22 Paradeniz			
Sampling period	I	II	III	IV	I	II	III	IV	I	II	III	IV
pH	8.02	7.97	8,22	8.4	8.3	8.23	8,6	8.14	8.05	7.98	8.24	8.18
T (° C)	27.5	27.2	14,3	18.6	33.9	30	11,3	19.1	31	29.1	11.1	22.7
EC		385	572	568		494		728		48000	33900	35200
(µS/cm)	335				439		760		45300			
sal	0	0	0	0	0	0	0,1	0.1	29.6	31.2	20.8	22.1
DO		6.8		5.77		7.8		3.63		5.4	9.2	8.13
(mg/L)	7.1		6,32		5.5		8,32		4.9			
NO_2^-		0	0,06	0		1.31	0	0.03		0.033	0	0
(mg/L)	0				0				0			
NO_3^-		6.9	17,3	8.4		4.6	6,6	9.3		3.6	0	0
(mg/L)	9.74				6.64				0			
NH_3		0	0,02	0.012		0	0	0		15.68	0.27	0
(mg/L)	0.048				0.34				4.01			
PO_4^{-3}		0	0,28	0.03		0.08	0	0.04		0.3	0.59	0.06
(mg/L)	0.05				0.88				0.39			
P^5		0.1		0.7		1	0	0.2		0.4	0.3	0
(mg/L)	0.2		0,7		1.4				0.2			
Br^-		0.67		0.75		0.52	0,78	0.54		0.43	0.59	0.52
(mg/L)	0.53				0.72				0.42			

I^- (mg/L)	0.4	2.8	0	0.2	0.4	0,3	0.3	3	1.6	0.7	1.2
F^- (mg/L)	0.12	0	0.26	0.83	0.42	0,4	0.53	0.81	1.85	1.15	1.2
Na^+ (mg/L)	5.71			21.7				9556			
K^+ (mg/L)	1.16			1.86				396			
Ca^{+2} (mg/L)	42.5			36.5				350			
Mg^{+2} (mg/L)	17.4			23.8				717			
HCO_3^{-2} (mg/L)	158			213				128			
Cl^- (mg/L)	10.8			22.5				15177			
$SO4^{-2}$ (mg/L)	24.4			34.4				2470			
KOI (mg/L)	22			16				1050			
Fe (mg/L)	0.64	0.0876	0	0.5	0.49	0,11	0.03	0.5	0.94	0.08	0.05
Cu^{+2} (mg/L)	0	0.2	0	0.9	1.21	0	0	0.4	0.23	2.81	1.01
Cr^{+6} (µg/L)	0	0	0	0	0	0	0	0	0	0	0
Mo^{+6} (mg/L)	0	0	0	0	0	0	0	0	0	0	0
Mn^{+2} (mg/L)	0	0	0	0	0	0	0	0	0	0	0
SiO_2 (mg/L)	5.2	0.087		17.4	5.68	16		7	7.4	25	

ME-6 Mediterranean				ME-7 Spring				ME-8 Göksu			
I	II	III	IV	I	II	III	IV	I	II	III	IV
7.91	7.9	8.21	8.12	7.65	7	7.4	7.9	7.94	8.08	8.45	8.9
29.2	27	15.3	20	22.8	24	19.7	21.1	30.1	26.7	13.9	18.4
53500	52100	58000	54000	974	1016	1372	1293	1800	405	690	464
35.5	34.3	38.1	35.3	0.3	0.3	0.5	0.4	0.7	0	0.1	0
4.7	4.5	8.1	8.9	7.5	5.9	4.4	5.2	6.4	6.4	6.6	8.4
0	0.033	0	0.03	0	0.13	0.03	0	0.23	0	0	0
6.64	2.5	0	0	17.72	2	3.5	2.6	3.1	5.2	41.2	1.6
4.01	2.27	2	4.5	0.17	0	0	0	0.07	0.02	0.32	0.01
0.2	0.04	0.14	0.25	0.06	0.11	0.42	0.52	0.27	0.02	0.58	0.51
0.7	0.3	0.2	0.2	0.5	0.1	0.1	0	0.6	0.6	0.4	0
0.58	0.55	5.37	0.52	0.93	5.15	0.57	0.49	0.53	0.6		0.52
0.2	26.8	2.9	1.2	0.1	0.4	0.3	0.1	0.5	0.3		0.2
1.96	1.93	1.7	2.0	0.1	0.31	0.15	0.22	0.33	0.07		0.15
10934				70				243			
485				3.89				11.5			
373				70.8				37.3			
822				36.3				39.7			
140				328				206			
17929				118				371			
2915				46.3				86			
1000				0				137			
0.06	0.696	0.21	0.03	0.4	0.834	0	0	0.13	0.69		0
0.77	0.43	0.12	0.1	0.6	0.65	0	0	0.29	0.31		0
0.048	0	0	0	0.024	0	0	0	0.021	0.05		0
0	0	0	0	0.1	0	0	0	0	0	0	
0	0	1.2	3.4	0	0	0	0	0	0		0
0.14	1.53	10		8	14.6	47		0.5	5.2		

Measurements of EC and pH were made in the field using a pH/Cond 340i WTW meter. For the pH measurements the electrode was calibrated against pH buffers at each location. Aliquots were filtered through a 0.45-mm Millipore cellulose type membrane and stored in HDPE bottles. The sample bottles were rinsed three times with the filtered sample water before they were filled. Then, 0.25 ml/L of HNO3 (nitric acid) was added to the first aliquot to prevent precipitation. The samples were refrigerated at 4^o C until analysis. The samples were analyzed in the laboratory of General Directorate of Mineral Research and Exploration (MTA) of Turkey in Ankara. Cations were analyzed by inductively coupled plasma (ICP) and anions by ion chromatography (IC). SiO_2 was analyzed mainly by visible spectrophotometer. Bicarbonates were determined by titration in the laboratory. Heavy metals and other pollutants in water were measured with Hanna C200 multiparameter photometer. Hanna C 200 Series is a line of 15 different bench, microprocessor based photometers that measure up to 46 parameters in water and wastewater. Followed by water quality analysis, thematic maps were generated and digitized using MapInfo GIS software, where spatial analysis and integration were carried out for drinking and irrigation water quality mapping in the basin.

The measured pollutant are compared with the Turkish Water Pollution Control Regulation (2001) and with the international standards like WHO (1996) and EPA (1995).

4. DISCUSSION

A lack of sewage disposal and of solid waste disposal systems is threatening water resources in urban areas. In all towns on the Göksu delta, there is no domestic waste collection. Thus, waste disposal create serious pollution of groundwater and surface water resources, especially where there is no control of waste disposal in or near bodies of water. Unfortunately, most sewage with pollutant levels above the level permitted by national standards is allowed to drain into natural bodies of water without any treatment, thereby polluting most creeks and Göksu river in and near Silifke city, because there was not any sewage treatment plants until 2007. In 2007 a new sewage treatment plants was established in Silifke city.

The land in Göksu Delta is used widely agriculturally (Fig. 2). Agricultural practices result in non-point-source pollution of surface water. Such sources include fertilizer and manure applications to increase grain yield and income, farmers are currently decreasing their use of organic fertilizer in favor of inorganic fertilizers with improper proportions of nitrogen, phosphorous, and potassium. The drainage water and irrigation return flow transport the fertilizer into groundwater and surface water. In the study area, the consumption of fertilizers amounts to 520 kg/ha.

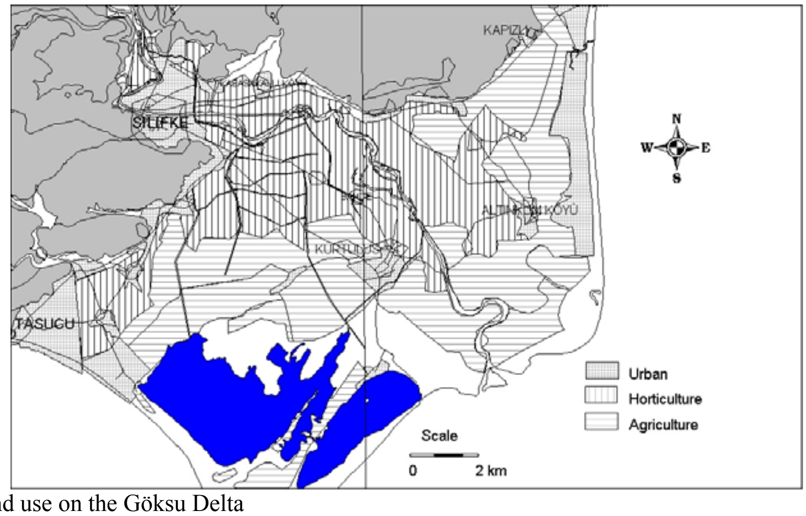

Figure 2. Land use on the Göksu Delta

Concentrations of major chemical elements in the surface water were related to the distance downstream from the source of the river, with surface water in the upstream reaches of good quality, but the river from Silifke city to the Mediterranean Sea is seriously polluted.

There was a wastewater outlets until 2007 that discharge a total of 10700 m^3/day into the river from Silifke city, which, combined with the agricultural activities, were found to be the major causes of water pollution. In addition, there are much wastewater outlets from the town that discharge into the Göksu River between Silifke city and Mediterranean Sea. On all the 365 days of the year, fecal matter, waste clothes, food materials can be observed at sampling station Sökün Bridge (Fig. 1). However, the surface water samples are characterized by a high degree of variability with respect to EC, which ranges from 335 to 58000 µS/cm. All the major ions and indicator for pollution such as salinity, NO_3, NH_3, PO_4 and some of the heavy metals also increased sharply downstream from Silifke city to Mediterranean Sea. The water of Akgöl Lake is unaffected from the anthropogenic activities in the study area and has Mg-Ca-HCO_3 character. But Paradeniz Lake is a saltwater lagoon connected to the sea and the chemistry of Paradeniz water is similar to the Mediterranean Seawater. The water type of Göksu River is Ca-Mg-HCO_3 in upstream, but after the Silifke it changes and the Na and Cl ions are added in the types of groundwater (Table 2, Fig 3 and 5).

Table 2. Chemical characters of surface waters

Sample	Location	Chemical character
ME-17	Göksu, before reaching to Silifke	Ca-Mg-HCO3
ME-19	Akgöl Lake	Mg-Ca-HCO3
ME-22	Paradeniz Lake	Na-Cl
ME-6	Mediterranean Sea	Na-Cl
ME-7	Olukbaşı spring	Ca-Na-Mg-HCO3-Cl
ME-8	Göksu after Silifke	Na-Mg-Cl-HCO3

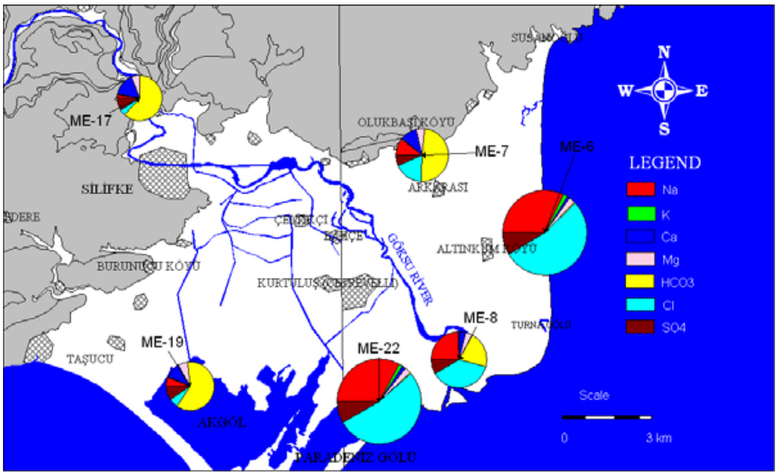

Figure 3. Thematic map for chemical characters of surface waters

The consantrationaly the chemical oxygen demand and dissolved oxygen are 22 and 7.1 mg/L at the sampling point ME-17 (upstream) and they changed to 137 and 6.4 at the sampling point ME-8 (downstream) (Fig. 4). The comparison of the chemical analyses of sampling points ME-17 and ME-8 indicate that the pollution is from Silifke city. This is deduced especially from the values of electrical conductivity and salinity. Except these the concentrations of NO_3, NH_3 and PO_4 increase due to agricultural activities and sewage.

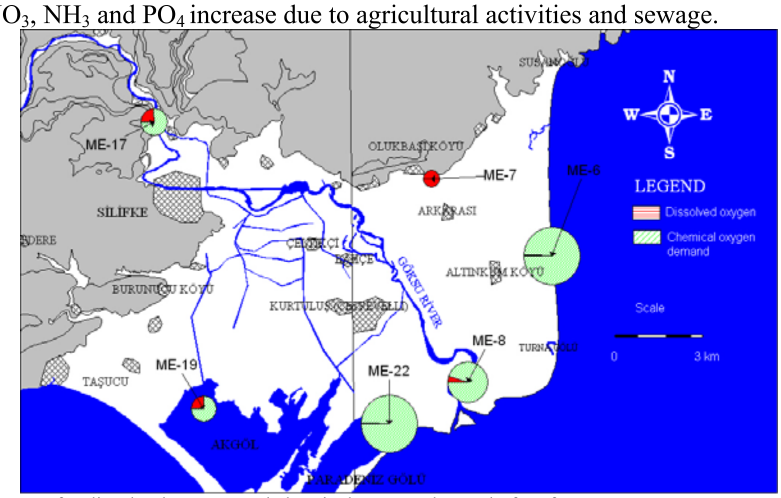

Figure 4. Thematic map for dissolved oxygen and chemical oxygen demand of surface waters

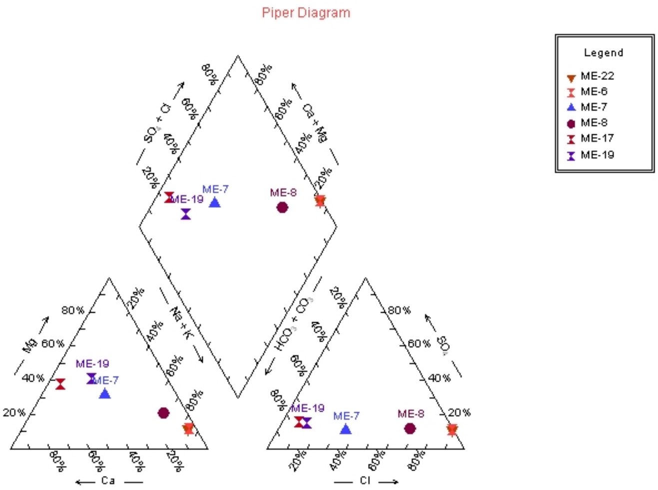

Figure 5. The Piper diagram

Agricultural activities are the main source for nitrate pollution in water (Carey and Llyod, 1985, De Simone and Howes, 1998, Gusman ve Marino, 1999; Birkinshaw ve Ewen, 2000; McLay et al, 2001; Ledoux et al., 2007; Oyarzun et al., 2007). Nitrate is very mobile in water (Meisinger and Randall, 1991; Birkinshaw and Ewen, 2000; Shamrukh et al, 2001). A high concentration of nitrate is generally attributed to anthropogenic sources. As Göksu Delta is surrounded by an area rich in citrus orchards, traditional farms and greenhouses, an agricultural source for NO_3 and SO_4 is possible. Use of fertilizers and pesticides is very widespread practice for agricultural activities in the area. The occurrence of high concentrations of nitrate and sulfate in all periods samples also coincides with the highest irrigation frequency (during the early periods of plant/vegetable development). The range of nitrate is found to vary between 0 to 41.2 mg/l. NO_3 concentration in this region is higher than Turkish limit value of 22 mg/l. The chemical analyses for nitrate for April 2008 show that the highest concentration is found in sampling point ME-8 (Sökün Bridge) where the land was intensively agricultural used (Fig 1 and 2). The phosphate concentration gives the similar results (Table 1). As indicated by Alloway (1995) the heavy metal sources of intensive farming regions could be mineral fertilizers (Cd, Cr, Mo, Pb, U, V, Zn) and pesticides (Cu, As, Pb, Mn, Zn). Cetinkaya (1996) reported that about 94 ton pesticides and 431 ton mineral fertilizers were used within a year at Goksu Delta . The pesticides and fertilizers contain also some heavy metals such as F, Br, Sn, Cl, Cu, Mn, Fe, Z Se, Co, Cd, Mo, Ni Pb and these are the source of water pollution. The Cr concentration of the river water is increased from 0 to 0.021 mg/l at the sampling point ME-8. Iron and cupper concentrations are also increased from 0 to 0.69 and 0.31 mg/L in down stream, respectively. These high heavy metal concentrations found at sampling point ME-8, may be related to the agricultural activities.

A model regarding DO (dissolved oxygen) and BOD (biochemical oxygen demand) was developed to assess the extent of pollution load in river Göksu. For the study of water quality modeling of river Göksu, water samples were collected from different sampling stations in February 2007 (Fig 6 and Table 3).

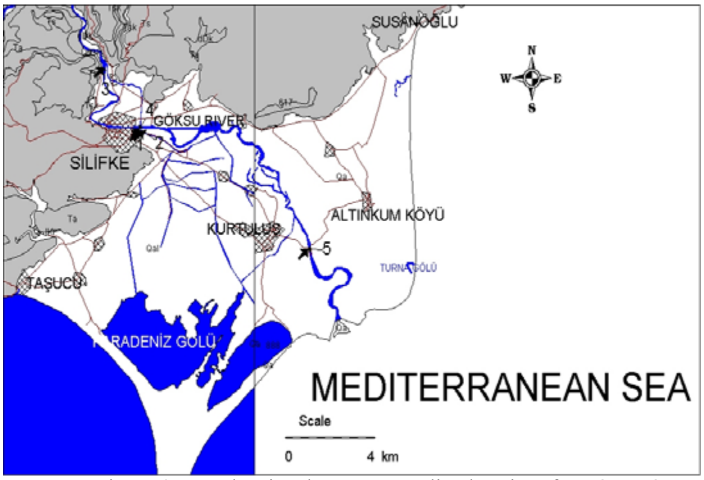

Figure 6. Map showing the water sampling locations for BOD-DO modeling

Table 3. Results of analyses for BOD-DO modeling

	(1) West sewer system	(2) Mixing point	(3) Regulator (before Silifke city) Upstream	(4) West sewer system	(5) Sökün bridge (after Silifke city) Downstream
pH	7,69	8,16	8,53	7,4	8,35
Temperature^{o}C	17	13	13.6	17.9	13.6
Electrical conductivity µS/cm	1591	405	393	1330	382
salinity	0.6	0	0	0.5	0
Dissolved oxygen (DO) (mg/L)	0.1	7.9	8	0	7.2
Biological oxygen demand (BOD) (mg/L)	318	4	0	315	0

BOD-DO River models deal with the oxygen household conditions of the river, by considering some of the main processes that affect dissolved oxygen (DO) concentrations of the water. These models are of basic importance since aquatic life, and thus the existence of the aquatic ecosystem, depend on the presence of dissolved oxygen in the water (Jolánkai G., 2000).The main process that affect (deplete) the oxygen content of water is the oxygen consumption of microorganisms living in the water, while the decompose biodegradable organic matter. Among external sources anthropogenic ones are of major concern and this include waste water (sewage) discharges and runoff induced non-point sources of diffuse loads of organic matter. Another main process in the oxygen household of streams is the process of reaeration, the uptake of oxygen across the water surface due to the turbulent motion of water and to molecular diffusion. These two counteracting processes are considered in the traditional BOD-DO model (Streeter and Phelps, 1925) on the mathematical form. The wastewater discharge into the Göksu River from Silifke city is a total of 10 700 m^3/day. The dilution equations compute the initial concentration of BOD as 0.29 and DO as 7.99 mg/L in the river downstream of point source sewage discharge, with the assumption of instantaneous mixing. This calculated dissolved oxygen contends is similar with the measured contend at mixing point and this is important for the calibration of the model. The initial oxygen deficit (for 13.6^{o} C) of the water is calculated as 2.5 mg/L. The oxygen sag curve has a critical point where the DO content of water is the lowest that is when the oxygen deficit is highest. The result of modeling show that, there is not occurred a critical point in Göksu River, the reason is the hipher flow rate of Göksu river (Fig. 7).

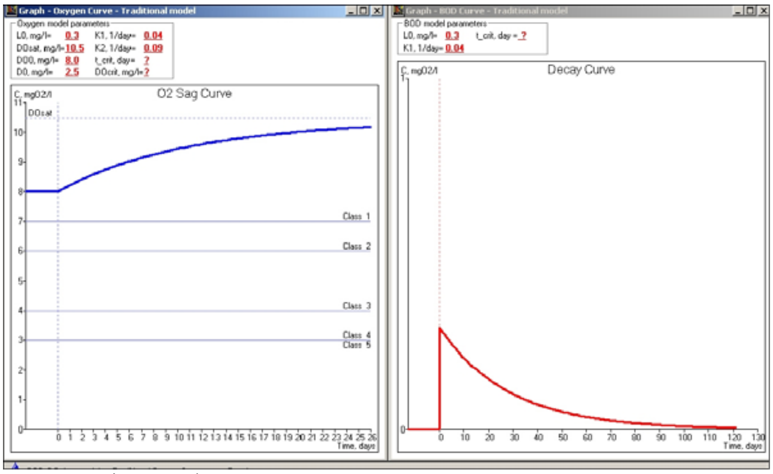

Figure 7. The oxygen sag curve

5. CONCLUSIONS

The ion and pollutant concentrations in the water of Göksu River change before and after Silifke city, making the water in the study area unsuitable for use in irrigation. The substances released by humans include industrial wastes, domestic sewage, rubbish, organic and inorganic fertilizers, and pesticides, which include a range of substances that are harmful to humans. These pollutants transported to surface water in various ways, leading to deterioration of water quality.

Waters in the river at the mountain and piedmont sites are of good quality with the EC below 500 µS/cm. However, the organic pollutants, including COD, BOD NH_3 and NO_3 followed sharply increasing trends from Silifke city to Mediterranean Sea. The chemical character of Göksu river water changes after the Silifke city and also the COD increases from 22 mg/L to 137 mg/L, DO decreases from 7.1 to 6.4 mg/L in downstream. These are the indicators for urban pollution from Silifke city.The range of nitrite is found to vary between 0 to 1.31 mg/L. NO_2 concentration in the surface waters of Göksu delta is higher than Turkish limit value in some periods. The range of nitrate concentration is found to vary between 0 and 41.2 mg/L for 2006-2008 and the ammonium in the water of Paradeniz Lake is determined between 0 and 15.68 mg/L. Comparing these concentrations with Turkish standard shows that in many points exceed the limits. The range of phosphate is found to vary between 0 to 0.88 mg/L. Phosphate concentration in this region is also higher than Turkish standard.

The F concentration of the surface water is changed between 0 and 2 mg/L during 2006 and 2008 sampling. Comparing this concentration with Turkish standard (1 mg/L) show that in many sampling points exceed the limit is exceeded. The range of iron is found to vary between 0 to 0.94 mg/L. Fe concentration in this region is higher than EPA limit value of 0.3 mg/L. Fresh water contains in general no copper. The copper concentrations of the samples change between 0.0 and 2.81 mg/L, and it exceeds the limit value of 0.05 mg/L of Turkish standard. The Cr and Mn concentrations of the surface water change between 0 and 0.05 mg/L and between 0 and 3.4 mg/L, respectively.

Agricultural sources of pollution focused on pesticide and fertilizer use. The source of excess concentration of various heavy metals is the agricultural activities and fertilizers. In the present study, the GIS technique has successfully demonstrated its capability in surface water quality mapping of the Göksu Delta. The final output has given the pictorial representation of water quality suitable or unsuitable for irrigation purposes in the basin. From the photometric heavy metal analysis, it is inferred that the excess concentration of some pollutants at some locations is the cause of undesirable quality for irrigation purposes. The source of excess concentration of various heavy metals is the agricultural activities and fertilizers. More rational use of fertilizers and pesticides will reduce their impacts on the water resources. It is determined that the heavy metals and other pollutants in the fertilizers and pesticides are transported easily to river water with irrigation return flow in the vicinity of Kapızlı, Altınkum and Kurtuluş towns.There was not a waste water treatment plant until 2007 in Silifke city; in addition, in all towns in Göksu Delta, there is not any domestic waste collection. Thus, waste disposal create serious pollution for Göksu River water.The water quality of Göksu River is modelled and determined that the waste water discharge of 10700 m3/day from Silifke city does not create a serious problem because of the high amount of flowrate of Göksu river. No critical point occurs where the DO content of water is lowest.

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