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Investigation of Groundwater Pollution in a Protected Area in Turkey, The Göksu Delta

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ABSTRACT

Göksu Delta is an important wetland where the Göksu River reaches the sea in the eastern part of the town of Taşucu-İçe1, Turkey. The delta is classified as a Wetland of International Importance according to the Ramsar Convention on Wetlands of International Importance. 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 content of all pollutants were determined during four different seasons between 2006 and 2008, and with these data a Geographic Information System (GIS) was constructed by using Map Info. The queries and thematic maps show the polluted wells and aquifer locations. From the photometric heavy metal analyses, it is inferred that the excess concentration of Fe, Ni, Mn, Mo and Cu at some locations is the cause of undesirable drinking water quality. The source of excess concentrations of various heavy metals is attributed to agricultural activities and fertilizers in the area.

Keywords: *Göksu Delta, heavy metal pollution, GIS*

1. INTRODUCTION

The Göksu Delta is particularly productive and formed by the Göksu River near the Southern part of Silifke, a town in Turkey's Mediterranean region (Figure 1). Göksu Delta is an important wetland (15000 ha) where the Göksu River reaches the Mediterranean Sea in the eastern town of Taşucu-İçel[1]. The delta is classified as a Wetland of International Importance according to the Ramsar Convention on Wetlands of International Importance. The Göksu Delta is additionally significant 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 [1,2].

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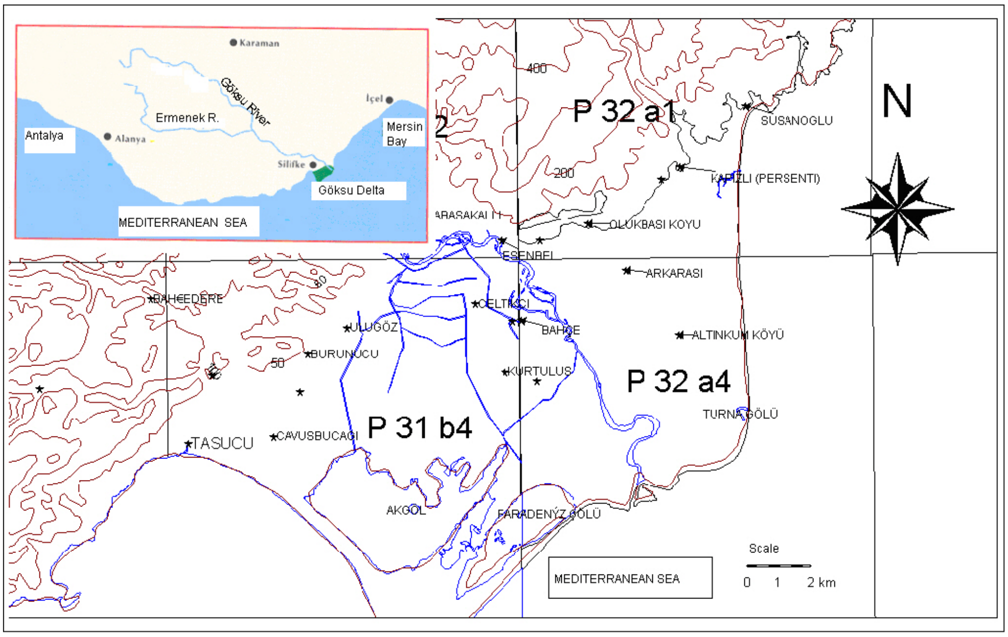

Figure 1. Map showing location of the Göksu Delta.

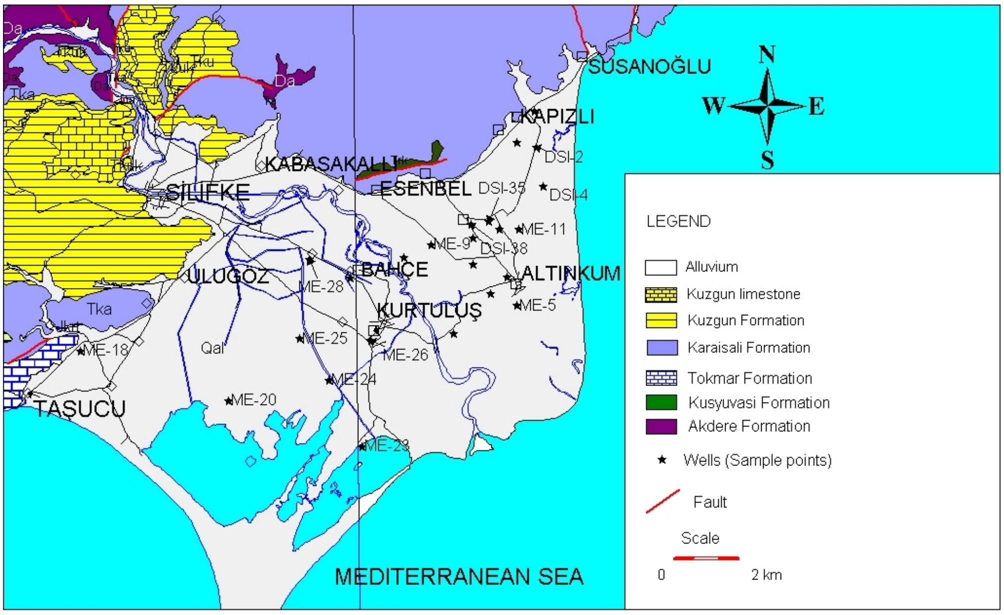

Figure 2. Map showing the water sampling locations and geology of the study area.

The Mediterranean coastline, stretching from the district of Silifke to the Susanoğlu region, is heavily populated due to urban developments (villas, apartments, complexes, and multi-storey buildings) in the last fifteen years, though most of these structures are occupied only in the summer months for vacation purposes. Because of an increased population influx from the surrounding cities, especially during the peak season (May to September), the population of this region has increased several fold. 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 the favorable climate.

In the Göksu Delta area, urban and agricultural expansions have caused an ever-growing need for freshwater. In this region, domestic water for urban developments and irrigation water for agricultural activities are almost exclusively provided through hand dug or drilled wells. In addition to apparent primary uses of water for domestic use (washing and bathing) the quantities required have been greatly increased by secondary demands, principally for gardening, landscaping, and water for swimming pools of the villas, apartment complexes, etc. These supplies are mostly required during the main holiday season, which coincides with the driest period. Therefore, water resources in the Göksu Delta area are subject to intensive demands, stresses and pollution risks [3].

Because the most widespread land use pattern in the delta is agriculture, agricultural inputs have caused high levels of contamination within the lagoons of the Göksu Delta. Indeed, previous studies indicated the presence of heavy metal and pesticide pollution in the area [1, 4, and 5].

In the previous studies, data showed that about 94 tons of pesticides and 520 kg/ha of mineral fertilizers were used within a year in the Göksu Delta [6]. Ayas et al. [1] reported that various environments (e.s river and lake) and organisms were contaminated by 13 different pesticides and their residues. It was determined that the use of pesticides in the Mediterranean region is more than the average consumption of all of Turkey [7]. Erdoğan and Karaca [8] reported that pesticide consumption was 9.9 kg per ha the types of pesticides are increased and 102 different types of pesticides were used in agricultural areas in the Göksu Delta. Additionally, the amount of fertilizers was 7200 tons in 2006. These pollutants affect the surface and groundwater quality negatively.

The purpose of this study is to investigate the pollution of groundwater and its source with photometric measurements in the basin and pictorially represent it using the Geographic Information System (GIS). The intensively used fertilizers and pesticides contain not only N- and P compounds, but also some heavy metals. The content of all pollutants are determined for four different seasons and with these data a Geographic Information System (GIS) is constructed by using MapInfo. The queries and thematic maps show the polluted wells and aquifer locations.

1.2. Site Description

The Göksu Delta is situated in the Mediterranean Sea region of the southeastern part of Turkey, and extends from 36^{o}15 –36^{o}25 of latitude north to 33^{o}55-34^{o}05 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.

In the Göksu Delta area, climate is characterized by hot and dry periods in the summer and by warm and wet periods in the winter, which is typical for the coastal zones around the Mediterranean Sea. The mean annual temperature in this area is 19^{o}C. Showers start in October and continue until 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 (3–4 months) without precipitation are common. The average flow of the Goksu River is 130 m^3/s and reaches its peak flow in May.

The study area was located in the southern part of Miocene carbonate rocks of the Taurus Mountains Belt. The oldest rock unit of the Göksu Delta is the Akdere Formation from the Paleozoic Age, which consists of marble, schist and quartzite. The Akdere Formation (middle-upper Devonian) is generally found in the northern part of the study area (Figure 2). It contains various rocks with differing compositions including sandstone, siltstone, dolomite and limestone. Kusyuvası Formation (Middle Trias) consists of limestone. The Tokmar Formation (upper Jura-lower Cretaseous) is found in the western part of the delta and contains dolomite and limestone. Tertiary units are composed of lower-middle Miocene Karaisali formation and middle-upper Miocene Kuzgun formation (Figure 2). Tertiary rocks consist of a succession of marine, lacustrine, and fluvial deposits, which display transitional characteristics both vertically and areally in 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, and 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 systems in the delta are a mixture of confined and unconfined aquifers. Recharge occurs by means of precipitation and infiltration at the top of the delta.

2. MATERIALS AND METHODS

For chemical analysis, water samples from 24 different well in the Göksu Delta (at the sampling points shown in Figure 2). were obtained between years 2006 to 2008 by four separate sampling campaigns. Table1 summarizes the chemical analysis results for water samples collected.

Table1. Analysis results for water samples taken from different wells. During four separate sampling campaigns between 2006 and 2008. (Concentrations are in milligram per liter)

Well Number	Date	pH	T(°C)	EC µS/cm	NO_2	NO_3	NH_3	PO_4	F	Mn	Fe	Cu	Mo	Cr
	07/2006	6.85	28.4	598	BD	7.08	BD	0.48	0.51	0.4	3.33	2.31	BD	BD
DSI-2	06/2007	6.80	27.9	641	BD	1.60	0.12	0.29	0.12	BD	1.88	0.53	BD	0.016
	07/2006	7.34	28.2	437	0.23	4.87	BD	0.84	0.01	28.6	0.11	5.5	2.3	BD
	06/2007	7.83	26.9	459	BD	5.70	0.05	0.15	0.54	0.1	1.88	0.37	0.1	0.020
	01/2008	7.93	12.7	448	BD	3.10	BD	0,29	0,6	BD	4,19	BD	BD	BD
DSI-20	04/2008	8.60	20.5	667	BD	7.53	0.07	0.8	0.65	0.2	BD	BD	0.3	BD
	07/2006	7.47	24.7	657	BD	7.53	0.27	0.17	0.35	BD	3.55	0.97	1.3	BD
	06/2007	7.18	24.0	762	BD	1.30	0.19	0.29	0.97	0.1	1.9	0.89	0.1	BD
	01/2008	8.02	16.1	1295	BD	BD	0,17	0,26	1	0,3	1,57	BD	0,1	BD
DSI-35	04/2008	8.00	17.8	1308	BD	11.4	BD	1.97	1.13	0.3	0.04	BD	0.5	BD
	07/2006	7.40	21.1	920	BD	31.89	BD	0.18	0.03	BD	4.05	1.09	0.8	0.007
	06/2007	7.96	21.8	856	BD	3.40	BD	0.18	1.36	BD	0.82	0.35	BD	BD
	01/2008	7.90	19.1	864	BD	BD	0,03	1,38	1,2	BD	0,01	BD	BD	BD
DSI-38	04/2008	8.30	19.5	930	BD	10.60	BD	1.02	1.15	BD	0.01	0.01	BD	BD
	07/2006	7.32	25.9	531	1.25	10.63	BD	0.7	0.33	BD	8.46	1.05	BD	BD
	06/2007	7.10	27.8	481	BD	4.70	0.08	0.09	0.66	BD	2.04	0.61	BD	1
	01/2008	7.90	14.3	620	BD	0.88	BD	BD	0,8	2	3,49	1,16	BD	0,009
DSI-4	04/2008	8.20	19.8	987	0.03	6.20	0.24	0.02	0.81	1.9	0.02	0.92	BD	0.001
	07/2006	7.40	20.2	802	BD	11.07	0.06	0.08	0.57	BD	0.4	0.19	BD	7
	06/2007	7.93	27.0	453	BD	1.60	BD	2.8	0.45	BD	0.78	0.23	BD	BD
	01/2008	7.70	15.0	465	BD	3.10	BD	0,02	1	BD	0,28	BD	BD	BD
ME-10	04/2008	8.80	20.8	684	BD	11.50	BD	5.2	0.96	BD	BD	BD	BD	BD
	07/2006	7.80	23.2	1416	1.25	4.87	0.04	0.21	1.59	BD	0.8	0.24	BD	0.020
	06/2007	7.85	22.1	1425	3.5	2.20	0.12	0.1	0.44	BD	0.79	0.19	BD	BD
	01/2008	8.20	12.3	1576	BD	7.50	0,49	0,12	0,6	BD	0,3	BD	BD	BD
ME-11	04/2008	8.40	21.8	1825	0.32	2.70	0.52	1.43	0.72	BD	0.02	BD	BD	BD
	07/2006	7.06	25.5	850	BD	18.60	BD	0.84	0.47	BD	0.07	0.06	1.5	0.021
	06/2007	6.90	25.0	904	BD	7.10	BD	0.06	0.25	BD	0.87	1.04	BD	BD
	01/2008	7.30	14.8	866	BD	8.80	BD	0,03	0,1	BD	0,45	BD	BD	BD
ME-13	04/2008	7.48	20.6	1024	BD	12.40	0.12	1.6	0.12	BD	BD	BD	BD	BD
	07/2006	8.10	23.7	1085	BD	4.87	0.63	1.38	1.17	BD	0.2	0.68	BD	0.052
	06/2007	7.90	26.6	1058	0.23	0.80	0.11	0.42	0.98	BD	0.656	0.35	BD	BD
	01/2008	8.31	8.8	1132	BD	8.40	BD	0,18	1,1	BD	0,34	BD	BD	0,002
ME-2	04/2008	8.70	27.1	1247	BD	3.10	0.12	3.6	1	BD	0.2	BD	BD	BD
	07/2006	7.94	20.7	434	BD	17.30	0.01	0.3	0.09	BD	5.5	0.21	BD	BD
	06/2007	8.13	21.7	435	BD	1.60	0.01	0.02	0.28	BD	4.95	0.11	BD	BD
	01/2008	8.50	19.4	699	BD	7.50	BD	0,11	0,1	BD	0,1	BD	BD	BD
ME-25	04/2008	8.38	20.5	527	BD	7.08	BD	0.19	0.23	BD	0.03	0.01	BD	BD

Table1. Analysis results for water samples taken from different wells. During four separate sampling campaigns between 2006 and 2008. (Concentrations are in milligram per liter)

Well Number	Date	pH	T(°C)	EC μS/cm	NO_2	NO_3	NH_3	PO_4	F	Mn	Fe	Cu	Mo	Cr
	07/2006	7.20	21.4	788	0.03	11.40	0.23	0.29	0.39	BD	1.27	0.15	BD	BD
	06/2007	6.87	22.1	914	BD	15.10	BD	2.68	0.45	BD	BD	0.19	BD	1
	01/2008	7.80	18.6	1212	0,06	18.10	BD	0,12	0,07	BD	0,09	BD	BD	BD
ME-27	04/2008	7.48	21.4	843	0.03	24.80	BD	0.14	0.83	BD	BD	BD	BD	BD
	07/2006	7.72	21.4	1510	0.3	11.80	BD	2.75	1.09	0.9	5.5	1.88	5.6	0.026
	06/2007	7.30	22.6	970	2.73	3.40	0.11	0.12	0.13	BD	5.74	0.13	BD	BD
	01/2008	7.85	20.0	2030	BD	BD	0,65	1,29	0,11	0,4	5,5	BD	BD	BD
ME-4	04/2008	8.13	21.1	2080	0.23	3.10	1.09	3.2	0.15	BD	0.01	BD	BD	BD
	07/2006	7.54	22.8	2260	1.25	11.80	0.06	0.3	0.47	BD	3.28	0.54	1	0.051
	06/2007	7.43	26.6	1430	0.36	4.00	0.12	0.35	0.96	BD	7.92	0.38	0.1	BD
	01/2008	7.73	18.8	2930	1,25	27.40	0,19	0,17	0,7	0,1	1,38	BD	0,2	BD
ME-5	04/2008	8.04	21.5	1575	1.316	7.50	1.15	1.72	0.9	0.1	0.02	BD	0.3	BD
	07/2006	8.48	20.8	716	BD	6.60	BD	0.18	0.51	BD	1.54	0.27	BD	0.023
	06/2007	7.93	23.3	837	BD	3.40	BD	1.28	1.05	BD	1.95	0.94	BD	BD
	01/2008	8.70	16.0	814	BD	6.64	BD	0,33	0,92	BD	0,1	BD	BD	0,027
ME-9	04/2008	9.03	20.3	1075	BD	5.30	BD	0.9	1.1	0.1	0.09	BD	0.1	BD
	07/2006	8.10	21.5	1476	BD	12.80	BD	0.31	0.96	BD	0.09	0.23	BD	0.025
	06/2007	8.45	21.0	1490	1.02	11.80	0.13	0.15	1.24	BD	0.734	0.12	BD	BD
	01/2008	8.19	18.5	1546	BD	4.43	0,1	0,22	1,1	BD	0,23	BD	BD	BD
ME-8-A	04/2008	8.50	21.2	1755	BD	3.50	0.28	0.34	1.3	BD	BD	BD	BD	BD
	07/2006	7.39	23.4	1220	0.1	1.50	0.13	1.35	0.93	BD	7.5	0.27	0.3	0.047
	06/2007	7.55	23.9	1146	BD	2.30	0.05	0.48	1	BD	8.12	0.05	BD	BD
	01/2008	7.67	20.1	1412	BD	6.20	0,99	0,33	0,9	BD	1,44	BD	BD	0,002
ME-1	04/2008	7.80	22.6	1710	BD	2.70	0.89	1.49	0.9	BD	0.12	BD	BD	0.002
	07/2006	7.56	21.3	1988	BD	1.80	BD	0.21	0.46	BD	0.2	0.37	BD	0.026
	06/2007	7.62	22.9	1894	BD	2.30	BD	0.1	0.62	BD	8.52	0.08	BD	BD
	01/2008	7.90	18.7	1404	0,06	1.32	0,02	0,02	0,9	BD	5,2	0,79	BD	BD
ME-12	04/2008	8.50	20.1	1470	BD	4.00	BD	0.38	0.8	BD	0.01	0.5	BD	BD
	07/2006	7.76	21.5	925	BD	15.90	0.07	0.23	BD	BD	3.41	0.41	BD	BD
	06/2007	7.73	23.1	751	BD	7.20	0.01	0.13	0.76	BD	7.16	0.48	BD	BD
	01/2008	7.92	19.1	925	BD	6.64	0,25	BD	0,5	BD	BD	BD	BD	BD
ME-20	04/2008	8.27	20.5	728	BD	BD	BD	0.11	0.6	BD	0.01	BD	BD	BD
	07/2006	8.12	22.0	2810	0.26	10.60	BD	0.45	1.97	BD	5.5	0.14	BD	BD
	06/2007	8.16	22.9	2830	2, 04	7.30	0.02	0.29	1.21	BD	3.48	0.19	BD	BD
	01/2008	8.80	19.2	3460	BD	5.30	0,77	0,28	2,2	0,2	0,01	BD	BD	BD
ME-23	04/2008	8.30	22.0	3420	0.6	1.80	0.7	0.22	1.9	0.5	0.02	BD	BD	BD
ME-24	07/2006	8.40	21.6	1031	BD	5.30	0.43	0.24	1.16	BD	5.5	0.35	BD	BD
	07/2006	7.84	26.0	711	BD	9.30	BD	0.13	0.21	BD	5.5	0.26	BD	BD
	06/2007	7.57	28.0	780	BD	4.60	BD	0.03	0.38	BD	BD	0.09	BD	0.029
	01/2008	8.50	14.5	1004	BD	7.50	BD	4,1	BD	BD	0,01	BD	BD	BD
ME-26	04/2008	8.13	21.4	3420	BD	3.90	BD	0.41	0.31	BD	BD	BD	BD	BD

Table1. Analysis results for water samples taken from different wells. During four separate sampling campaigns between 2006 and 2008. (Concentrations are in milligram per liter)

Well Number	Date	pH	T(oC)	EC µS/cm	NO2	NO3	NH3	PO4	F	Mn	Fe	Cu	Mo	Cr
	07/2006	7.45	21.5	598	BD	11.90	BD	0.42	0.3	BD	4.16	0.17	0.1	BD
	06/2007	7.07	21.7	601	BD	5.70	BD	0.26	BD	BD	7.46	0.27	BD	0.036
	01/2008	8.90	18.5	3050	0,06	8.86	0,3	0,2	0,19	BD	BD	BD	BD	BD
ME-28	04/2008	7.73	21.1	2830	BD	10.18	0.21	0.22	0.21	BD	BD	BD	BD	BD
ME-3	07/2006	7.42	23.2	756	0.26	9.70	BD	0.61	0.22	BD	0.8	0.29	BD	0.008
	06/2007	7.20	24.3	739	BD	2.80	0.4	0.14	0.21	BD	7.72	0.1	BD	BD
	01/2008	7.60	15.2	712	BD	2.21	0,23	0,13	0,2	BD	2,34	BD	BD	BD
	04/2008	7.65	26.8	1091	BD	7.50	0.68	0.54	0.23	BD	0.13	BD	BD	BD
	07/2006	7.17	21.5	719	BD	14.20	0.02	1.86	0.08	BD	2.07	0.24	BD	BD
	06/2007	6.95	30.9	753	BD	4.70	BD	BD	0.64	BD	0.804	0.05	BD	BD
	01/2008	7.90	11.7	932	BD	23.00	0,03	0,08	0,15	BD	0,01	BD	BD	BD
ME-18	04/2008	8.03	20.3	1003	BD	13.20	0	0.1	0.5	BD	BD	BD	BD	BD

*BD ; Below detection limit

Water samples obtained from the wells are from various depths because the wells in the area vary greatly in depth. Average well depth is 5 m for hand dug wells (shown as DSI) and 30-35 m for drilled wells (shown as ME). Electrical conductivity (EC), temperature (T) and pH were monitored during pumping, and samples were collected only when values stabilized or after at least three well volumes had been purged. 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-micrometer 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 HNO_3 (nitric acid) was added to the first aliquot to prevent precipitation. The samples were refrigerated at 4 ^{o} C until analysis. Samples were analyzed in the laboratory of Mersin University. Heavy metals in groundwater were measured with a Hanna C200 multiparameter photometer. The Hanna C 200 Series is a line of 15 different bench microprocessor based photometers that measure up to 46 parameters in water and wastewater. The measured pollutants were compared with the Turkish Water Pollution Control Regulation (TWPCR) [9] and with the international standards like WHO [10] and EPA [11].

The GIS constructed in this study includes groundwater quality data such as T, NO_2^-, NO_3^-, NH_3, PO_4^{3-}, Cr, Cu, Mo, Mn, and Fe. By using MapInfo many thematic maps and query maps are produced, and by overlaying these maps, agriculturally polluted areas are determined. Data for the thematic maps were selected from the database using SQL commands and MapInfo. A query using the SQL is created for those heavy metals which exceed the limits. Among various elements, it has been revealed that the Fe, Ni, Cu, Mn and Mo concentrations exceed the desirable limit in many locations. The values were plotted in the respective sample locations with a different symbol for four separate sampling campaigns (between 2006 and 2008).

3. DISCUSSION

In the Göksu Delta plain, the land is highly productive and used for agricultural purposes. Fertilizers and pesticides are used intensively to increase crop yields. Surface water from the Göksu River and groundwater obtained from a coastal alluvium aquifer is utilized for irrigation. Most of the irrigation return flow in the drainage canals discharges back into the Göksu River or leach to the groundwater and together transport some pollutants to those aquatic ecosystems. Besides the above mentioned pollution sources, manure and urban areas with their cesspools are other pollution sources for surface and ground waters in the Göksu Delta.

Agricultural activities are the main source for nitrate pollution in groundwater [12-18] and nitrate is very mobile in groundwater [15, 19, and 20].

A high concentration of nitrate is generally attributed to anthropogenic sources. An area rich in citrus orchards and traditional farms and greenhouses surround the Göksu Delta, so an agricultural source for NO_3^- and SO_4^{2-} is possible. In fact, the use of fertilizers and pesticides is a very widespread practice for agricultural activities in this area. The occurrence of high concentrations all periods' samples also coincides with the highest irrigation frequency (during the early periods of plant/vegetable development), which occurs during early summer (May–June). A possible mechanism for these ions in reaching the underlying aquifer can be their mobilization with the irrigation return water. High permeability units (due to coarse sand and gravel) within the study area possibly provide the fast pathways for the irrigation return water reaching the underlying aquifer in a relatively short time.

The groundwater samples collected from the Göksu Delta are colorless, odorless and free from turbidity. The temperature of the groundwater in the Göksu aquifer changes between 8.8 and 30.9 °C and it depends very strongly on the atmospheric conditions.

The range of nitrate is found to vary between 0 to 31.8 mg/LNO_3 concentration in this region is higher than the Turkish limit value of 22 mg/L (as set by the Turkish Standard). The thematic map for nitrate for April 2008 (Figure 3) and the thematic map for phosphate for 2007 (Figure 4) shows that the highest concentrations are found in the northern part of Kurtuluş where the land is intensively used for agriculture.

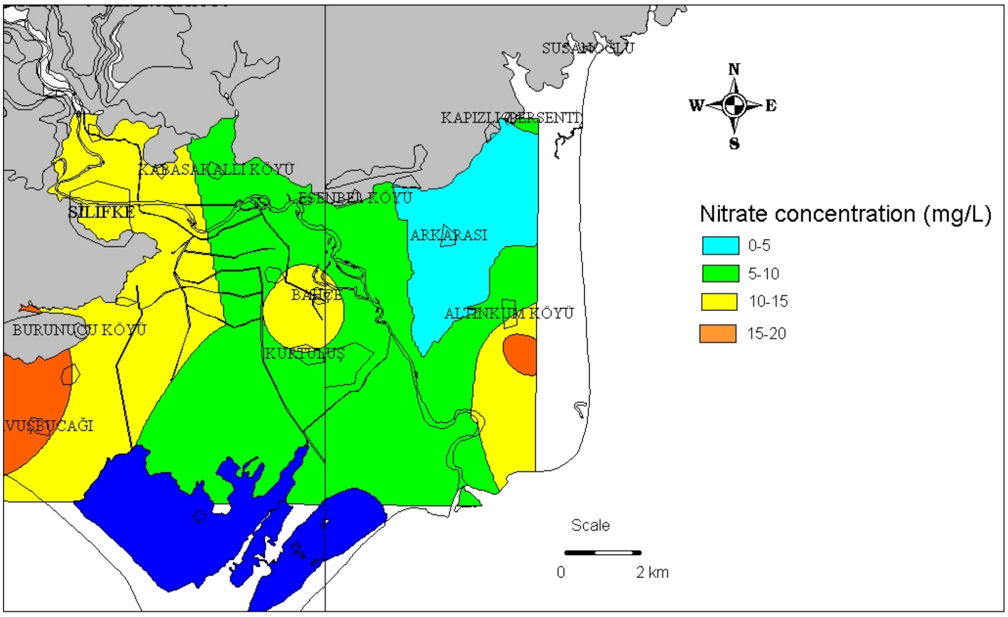

Figure 3. Thematic map for nitrate (April 2008).

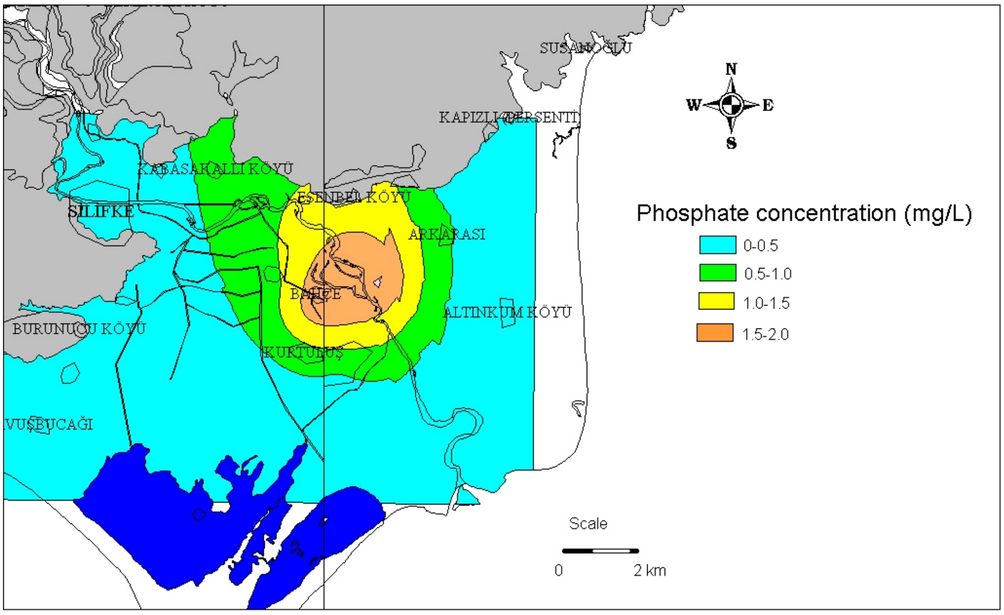

Figure 4, Thematic map for phosphate (July 2007).

As indicated by Alloway [21] 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). Çetinkaya [6] reported that about 94 tons of pesticides and 431 tons of mineral fertilizers were used within a year in the Göksu Delta. The pesticides and fertilizers also contain some pollutants and heavy metals such as F, Br, Sn, Cl, Cu, Mn, Fe, Z Se, Co, Cd, Mo, Ni Pb. According to the results of water sample analyses, there is a strong positive correlation between NO_3 and Cu, and Mo (Figure 5 and 6). Since there are no other source for metal contamination in the region, the heavy metal contamination is attributed to the agricultural activity.

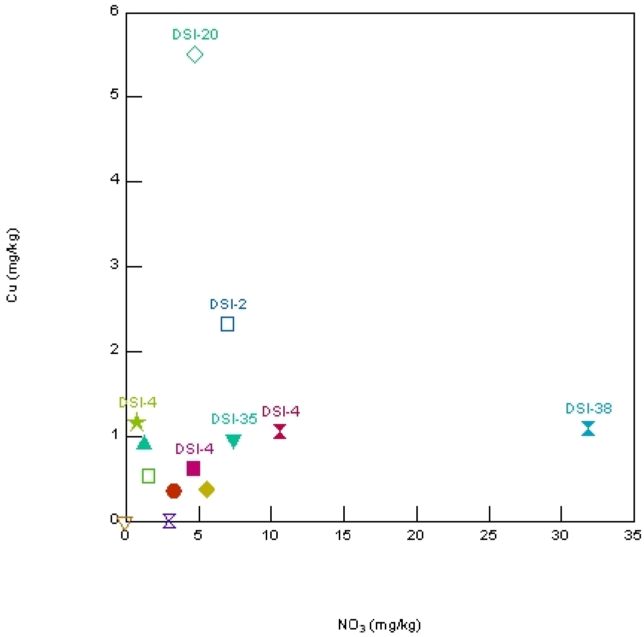

Figure 5. The relationship between nitrate and copper contents.

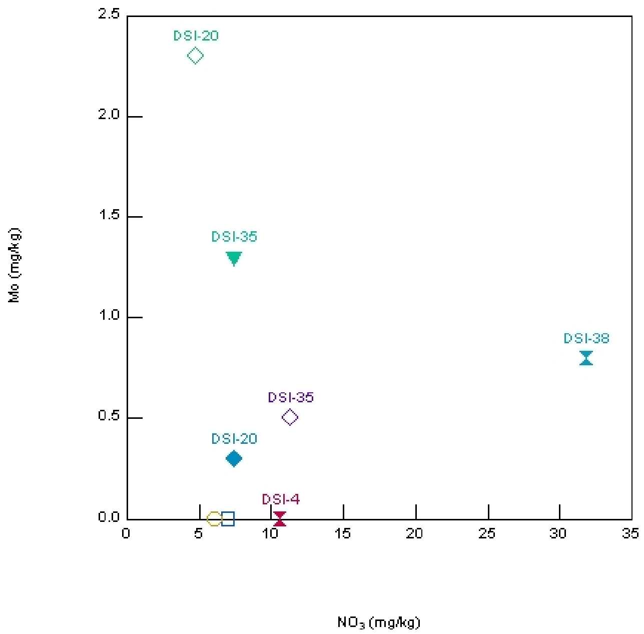

Figure 6. The relationship between nitrate and molybdenum contents.

Iron, copper, manganese, and chromium exhibit particularly high concentrations in Susanoğlu and Altınkum relative to the rest of the Göksu catchment

The Cr concentration of the groundwater changed between 0 and 0.052 mg/L during the 2006 and 2008 sampling. Comparing these concentrations with areas. There is not any geologic or anthropogenic source for these heavy metals in the study area; therefore these elements may come from fertilizers. TWPCR (0.02 mg/L) shows that many wells exceed the limits (Figure 7, 8 and 9).

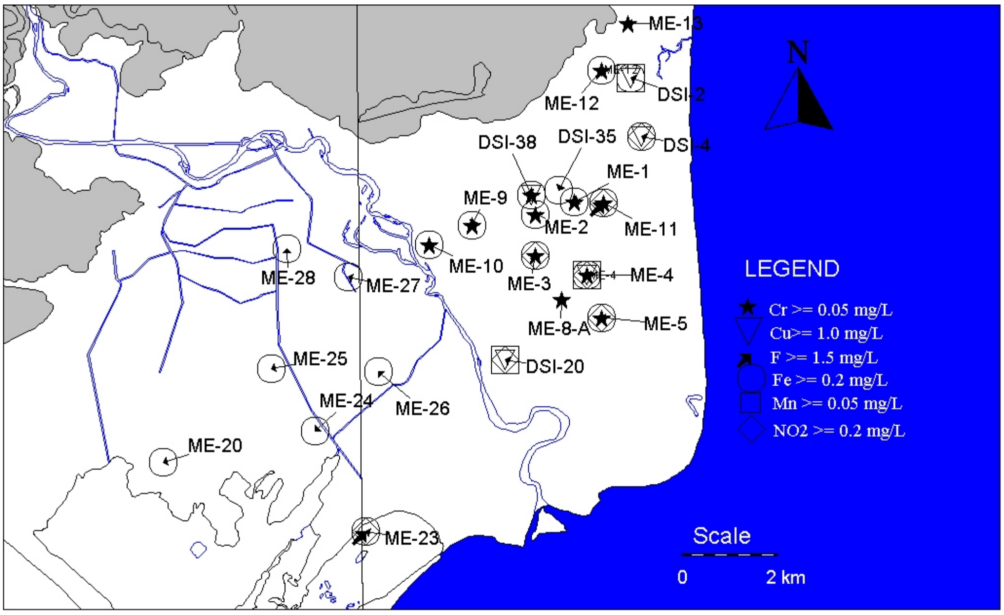

Figure 7. Heavy metal query map for 2006.

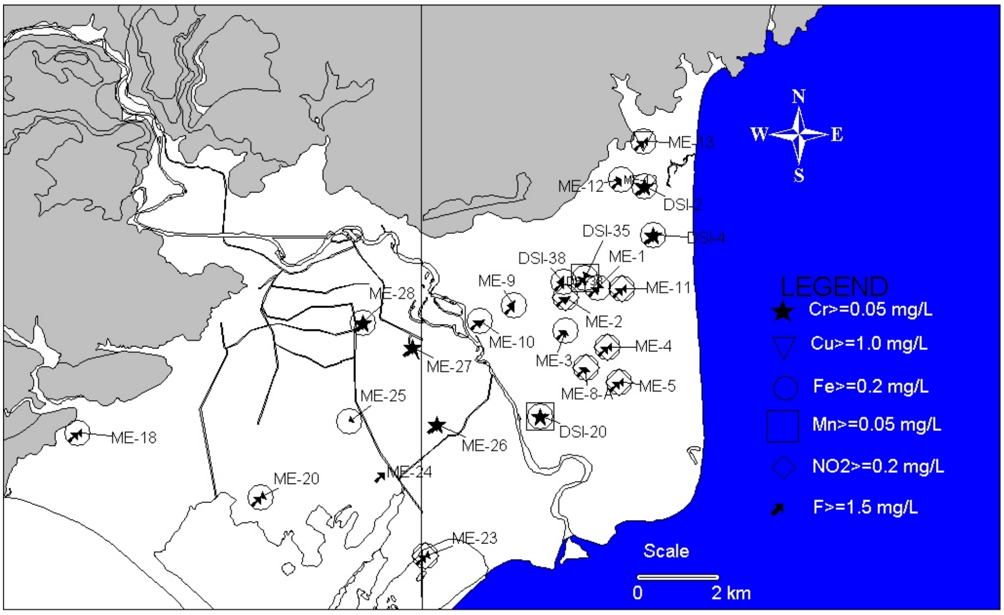

Figure 8. Heavy metal query map for 2007.

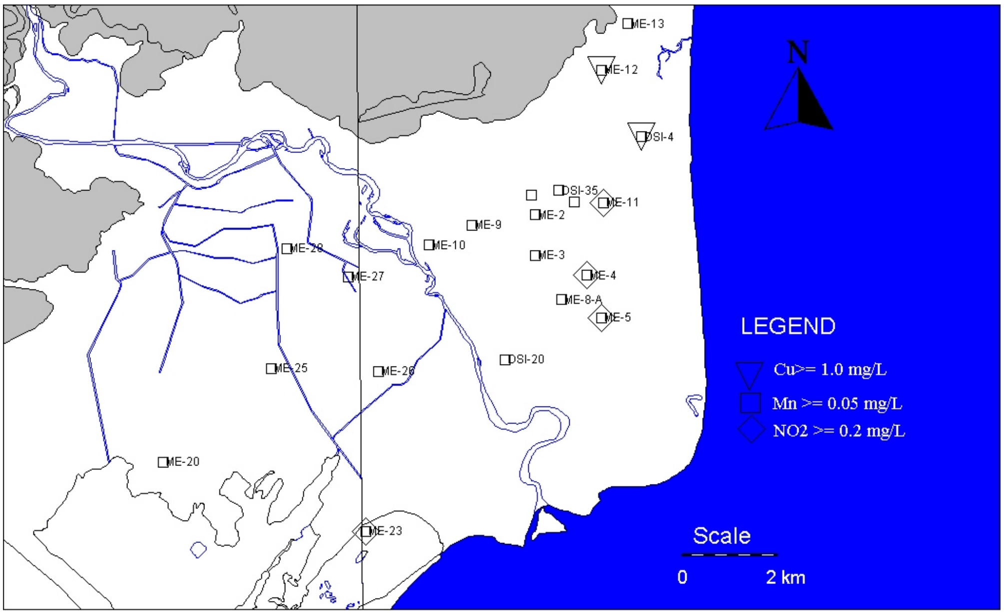

Figure 9. Heavy metal query map for 2008.

The range of iron was found to vary between 0 to 86.4 mg/L. Fe concentration in this region is higher than the EPA limit value of 0.3 mg/L. For the study area, it has been found that in 8 locations the iron concentration exceeds this limit. High iron concentrations are found within the central part of Göksu, and this may be related to the agricultural activities (Figure 7, 8 and 9).

The highest manganese concentrations, 2.8mg/L, were found in the groundwater in the Göksu Delta. For the study area, it was found that in many locations the manganese concentration exceeds the EPA and TWPCR limit (Figure 7, 8 and 9).The locations of Mn polluted areas show that the source of Mn pollution is also agricultural activity in Göksu.

Freshwater contains, in general, no copper. However, the copper concentrations of the samples change between 0.0 and 5.5 mg/L, and exceed the limit value of 1.0 mg/L (Figure 7, 8 and 9).

The range of molybdenum was found to vary between 0.0 to 5.5 mg/L where a WHO (1996) standard for the desirable limit of molybdenum is set as 0.07 mg/L. For the study area it was found that in many locations the molybdenum concentration exceeds this limit Figure 7, 8 and 9).

4. CONCLUSIONS

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 drinking water quality. The source of excess concentrations of various heavy metals can be attributed to agricultural activity and fertilizers.

It was determined that in all periods between 2006 and 2008 the heavy metals contained in the fertilizers and pesticides were potentially transported to groundwater with irrigation return flow in the vicinity of the towns of Kapızlı, Altınkum and Kurtuluş.

The Göksu Delta area is particularly vulnerable to agricultural pollution sources because rapid flow rates (due to coarse sediments) produce limited opportunity for natural processes that attenuate anthropogenic pollution.

The results of the analyses indicate that the groundwater cannot be used as drinking water.

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