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Water Quality of Surface Waters in Lower Euphrates Basin (Southeastern Anatolia, Turkey)

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Abstract: In this study, some physicochemical properties of surface waters of the lower Euphrates Basin in the Southeastern Anatolia region were investigated. The water sources investigated are Atatürk, Birecik, Karkamis and Haci Hidir Dam lakes and Euphrates River together with eight streams which are major running waters of the sub-basin. Total 20 variables consisting of temperature, pH, electrical conductivity, dissolved oxygen, turbidity, total dissolved and suspended solids, biochemical oxygen demand, total hardness, total alkalinity, calcium, magnesium, sodium, potassium, chloride, fluoride, sulfate, ammonia nitrogen, nitrate nitrogen and reactive phosphorus were monitored in surface waters. Significant relationships between dissolved ions, conductivity, hardness and alkalinity were observed. While most of the surface waters had middle hard and slightly alkaline characteristics with moderate dissolved solids and low organic matter content, Haci Hidir Dam lake and Nizip Stream separated from them in terms of investigated variables.

Key words: Lower Euphrates, surface waters, water quality, Southeastern Anatolia, conductivity, investigated variable

INTRODUCTION

Euphrates river with high surface water potential and with about 30×10^9 m^3 total annual discharge in boundary of Turkey is the most important running water of Turkey and Middle East (Kolars, 1994; Altinbilek, 1997). Extending for almost 3000 km, the Euphrates is the longest river in western Asia. Arising near Mount Ararat at heights of around 4500 m near lake Van, the Euphrates drops on average 2 m km^{-1} of length in Turkey and then crosses into Syria flowing South-East. The largest reservoirs of Turkey and Syria were constructed on the river (Altinbilek, 2004; Bayazit and Avci, 1997; Altinbilek, 2004).

Euphrates River takes its name by joining of the rivers Karasu and Murat near Keban District (Elazig, Turkey). Keban Dam, second largest dam of Turkey was constructed in this basin. Then, water discharged from the dam pours into Karakaya Dam lake that is the 3rd largest dam of Turkey. The following Ataturk Dam lake is one of the largest artificial lakes of the Europe and Asia in point of surface area and hydropower production. The next reservoirs of river prior to leave Turkey's boundary are Birecik and Karkamis Dam lakes. Total surface area of five large dams that constructed on Euphrates River Basin of Turkey is approximately 1850 km^2 (GAP, 2003, 2004).

The part of the river within Turkish territory was divided into three sub-basins due to highly wide catchment. The upper basin mainly consists of Karasu River catchment and Keban Dam lake Basin whilst the middle basin includes Murat River catchment. The lower basin covers an area from Karakaya Dam lake to Karkamis Dam lake.

These sub-basins display geographical and climatological differences. The upper and middle basins have relatively more altitude than the lower basin. Annual average precipitation of the lower basin in arid-terrestrial climatological zone is less than the other basins. Besides, its annual average temperature is higher than upper and middle basins (Bayazit and Avci, 1997; Altinbilek, 2004).

Length of main channel of Euphrates River in the last sub-basin is about 475 km that is about 1/3 of its total length in Turkey. The river's flow in this basin has been significantly altered in comparison to upper and middle basins. It has been mainly regulated for hydro-electrical power, agricultural irrigation and urban water supply.

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Although there is only one natural small lake in the lower basin, major surface waters are Euphrates River and its dam lakes.

In this study, some water quality properties of surface waters in Southeastern Anatolia Region of the Lower Euphrates River Basin were researched. With this purposes, Euphrates River and major eight streams in addition to Ataturk, Birecik, Karkamis and Haci Hidir Dam lakes were monitored by a sampling period of eight months during 2002 and 2003.

MATERIALS AND METHODS

Study area: The surface waters were sampled along Atatürk Dam lake inlet and Karkamis Dam lake outlet. One sampling point in Haci Hidir Dam Lake (HDL), two points in Birecik Dam Lake (BDL) and Karkamis Dam Lake (KDL) were monitored whilst six points in Ataturk Dam Lake (ADL).

Two points in Euphrates River (EPH) at outlet of Ataturk Dam and of Birecik Dam were monitored. One point was sampled in each stream Nizip (NZP), Goksu (GKS), Kalburcu (KLB), Kahta (KHT), Cakal (CKL), Egri (EGR), Cam (CAM) and Abuzergaffar (AGF). Thus, total 13 surface waters covering four dam lakes and nine running waters were investigated during the study (Table 1 and Fig. 1).

Table 1: Geographical co-ordinates and altitudes of sampling sites

Surface water name	Latitude (N)	Longitude (E)	Altitude (m)
Ataturk Dam lake	37°45'53"	38°58'17"	532
Ataturk Dam lake	37°43'27"	39°01'34"	
Ataturk Dam lake	37°30'16"	38°29'40"	
Ataturk Dam lake	37°28'59"	38°18'44"	
Ataturk Dam lake	37°24'15"	38°35'44"	
Ataturk Dam lake	37°39'56"	38°19'18"	
Birecik Dam lake	37°10'34"	37°50'49"	355
Birecik Dam lake	37°03'28"	37°53'10"	
Karkamis Dam lake	36°52'15"	38°02'01"	335
Karkamis Dam lake	36°57'05"	38°00'20"	
Haci Hidir Dam lake	37°42'50"	39°11'42"	622
Cam stream	37°42'43"	39°10'15"	598
Euphrates river	37°27'52"	38°15'52"	395
Euphrates river	37°02'01"	37°58'12"	340
Kahta stream	37°55'56"	38°36'30"	599
Kalburcu stream	37°42'43"	38°32'30"	560
Abuzergaffar stream	37°44'30"	38°20'05"	538
Cakal stream	37°43'21"	38°09'52"	621
Egri stream	37°43'09"	38°09'17"	650
Goksu stream	37°40'44"	38°05'15"	588
Nizip stream	36°57'34"	37°58'41"	351

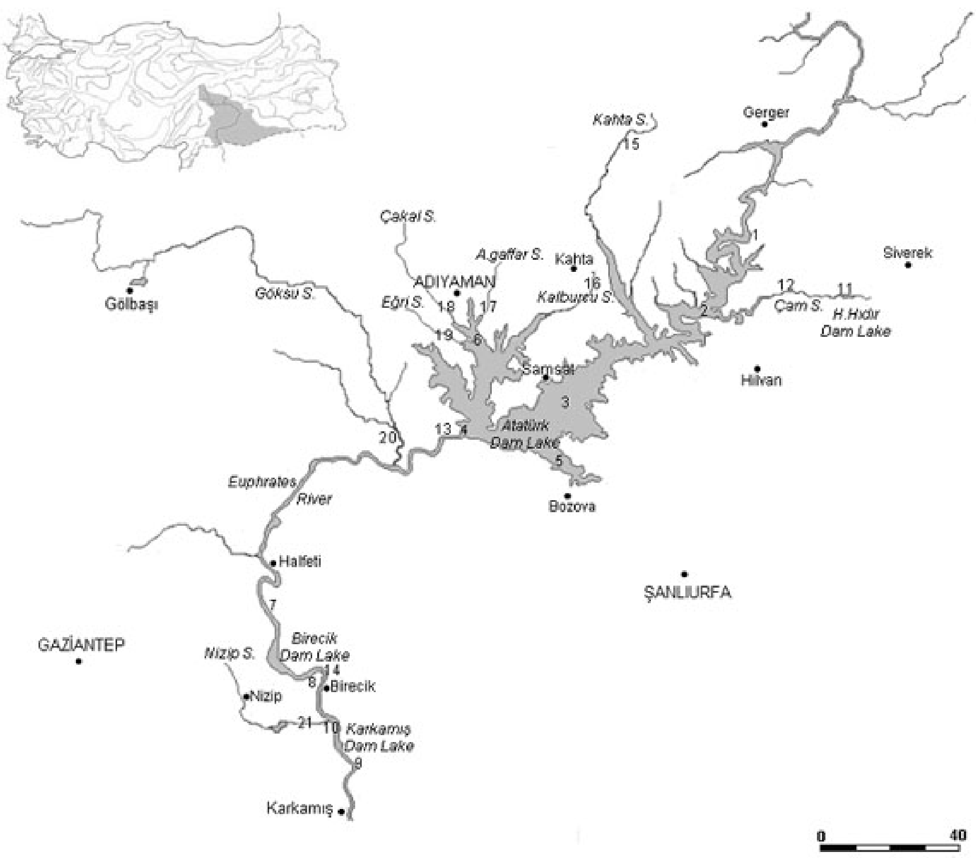

Fig. 1: Sampling points and surface waters in Southeastern Anatolia region of the lower Euphrates river

These surface waters which have similar climatic and geographic properties are located between north of the Southeastern Anatolia region and Syria boundary of Turkey. ADL (817 km^2) is bordered by Diyarbakir, Adiyaman and Sanliurfa whilst BDL (56 km^2) and KDL (28 km^2) are surrounded by Sanliurfa and Gaziantep. HDL which is a small lake constructed for agricultural irrigation (4.4 km^2) is in Siverek District of Sanliurfa. Most of the streams monitored in the present study are situated in ADL Basin. These streams generally arise from Malatya (2605 m), Gorduk (2007 m) and Karaca (1957 m) Mountains of Southeastern Taurus Mountains surrounding the northern boundary of the region. The other parts of the region are plain and elevation usually changes between 350 and 700 m. GKS arising from Nurhak Mountains (2269 m) has about 120 km length and is one of the most important tributaries of EPH. However, the other streams studied are relatively small running waters between 20 and 40 km (COB, 2004a-c).

In the studied region while mean annual temperature (16.7-18.8°C) do not display important changes, mean annual precipitation (460-798 mm) is relatively different. Since calcareous main rock is generally dominant in soils of the Southeastern region, most of the region is mainly covered by reddish brown and brown soils. An important part of region's soils (about 75%) contains calcium carbonate>15% level due to fact that main component of bedrock of the region is widely calcareous.

The other common type is basaltic soils especially in some volcanic areas. Agriculture is principal land use of the provinces and practiced on 50-90% of total land area. In the region, grassland (6-12%) and natural woodland areas (0-15%) are relatively poor as a consequence of primarily climate and geographic conditions (COB, 2004a-c).

Sample collection and analysis: Samples and measurements were taken from surface of littoral zone of dam lakes with a boat and and from banks of the running waters by hand. Temperature, pH, Electrical Conductivity (EC) and Dissolved Oxygen (DO) were measured in the field using YSI 63 and YSI 55. Water samples were collected into 2.5 L pre-cleaned polypropylene bottles and transported to laboratory at sampling day. Analyses of samples were carried out in the laboratory of XV Regional Directorate of State Hydraulic Works.

Samples were analyzed for 16 variables including Turbidity (Turb), Total Dissolved Solids (TDS), Total Suspended Solids (TSS), 5 days Biochemical Oxygen Demand (BOD), Total Hardness (Hard), total Alkalinity (Alk), Calcium (Ca), Magnesium (Mg), Sodium (Na), potassium (K), Chloride (Cl), Fluoride (F), sulfate (SO_4), ammonia nitrogen (NH_3-N), nitrate nitrogen (NO_3-N) and reactive phosphorus (PO_4-P). In analysis of water samples, gravimetric, titrimetric and colorimetric methods approved by Turkish Standards Institution were used (APHA, 1985).

Statistical analysis: Median, minimum and maximum values were separately calculated for 13 surface waters. A Spearman's correlation matrix was used to identify the strengths and probabilities of relationships among environmental variables. A total of 16 of the original 20 measured variables from 21 sampling points were used in statistical data evaluation. Temperature was eliminated from the dataset because the contributions of the values to results were not reasonable due to fact that measurements were not carried out monthly. Median values of dissolved oxygen, 5 days biochemical oxygen demand and fluoride were calculated but they were also eliminated from multivariate analysis dataset due to inconsiderable relationship with other variables. Unfiltered reactive phosphorus in CKL and EGR displayed extremely high values that might bias the mean values. However, as phosphorus was a potentially important variable and median values were used it was kept in the dataset and used in the statistical analyses. Although, nitrate nitrogen did not show an important relationship with other variables it was used in analysis like phosphorus. Moreover, some variables with no reasonable relationship with the others were retained in the dataset because did not effect on the principal directions of variation. Statistical analysis was performed using JMP (Version 5.0.1) demo version.

Data were standardized to mean zero and logarithmically transformed for multivariate analysis. Principal components analysis was used to interpret the major patterns of variation in the environmental data by examining the strengths of each variable in explaining the principal directions of variation for the 13 surface waters. Cluster analysis by the Spearman's correlation coefficient was used to measure to similarity of the river and dam lakes in the lower, upper and middle basins. Multivariate analysis was carried out using the MVSP (Version 3.1) demo version.

RESULTS

Major surface waters of Lower Euphrates Basin in Southeastern Anatolia Region were designated as soft-middle hard and slightly alkaline water sources with moderate TDS and low organic matter content. In general, median values of major ions for lakes were higher than

Table 2: Physiochemical properties including Median (med), Minimum (min) and Maximum (max) values for investigated surface waters in Lower Euphrates River Basin

Surface waters	pH			EC (µS cm^{-1})			DO (mg L^{-1})			BOD (mg L^{-1})			Turb (NTU)		
	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.
ADL	8.1	7.7	8.3	360	295	435	9.2	7.3	0.0	1.3	1.0	2.4	7.1	5.0	20.0
BDL	8.2	7.7	8.4	356	314	447	8.9	7.5	9.8	1.1	0.6	1.8	7.5	5.0	20.0
KDL	8.1	7.6	8.3	364	310	479	9.2	8.3	10.3	1.6	1.1	2.7	6.3	5.0	20.0
HDL	8.1	7.6	8.3	295	254	400	8.4	6.4	10.2	3.9	2.3	6.8	7.5	5.0	20.0
EPH	8.1	7.4	8.4	387	250	446	8.7	6.7	10.1	1.4	0.7	4.9	5.0	5.0	20.0
NZP	8.0	7.5	8.4	569	485	635	8.1	7.4	9.1	1.1	0.6	2.2	5.0	5.0	10.0
GKS	7.9	7.6	8.0	320	293	385	9.2	6.7	9.9	1.0	0.6	2.7	5.0	5.0	20.0
KLB	7.9	7.9	8.0	387	350	426	7.8	6.6	9.5	0.9	0.5	1.6	5.0	5.0	5.0
KHT	7.9	7.9	8.0	330	284	410	8.5	7.0	9.7	1.3	0.7	2.0	5.0	5.0	10.0
CKL	7.9	7.8	8.4	407	252	460	9.1	7.3	0.1	1.2	0.5	6.3	5.0	5.0	20.0
EGR	8.1	7.7	8.3	425	340	553	8.3	7.1	9.8	2.3	0.9	4.1	5.0	5.0	20.0
CAM	8.0	7.6	8.1	341	285	447	9.0	7.0	10.1	1.5	1.1	3.3	5.0	5.0	20.0
AGF	8.1	7.6	8.4	380	270	400	9.1	7.5	9.9	1.4	0.8	3.5	5.0	5.0	10.0

Surface waters	TSS (mg L^{-1})			TDS (mg L^{-1})			Alk (mg $CaCO_3$ L^{-1})			Hard (mg $CaCO_3$ L^{-1})			Ca (mg L^{-1})		
	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.
ADL	8.6	4.3	15.6	227	189	245	127	104	160	165	146	193	45.0	37.6	53.4
BDL	9.4	3.7	16.0	227	200	289	135	115	170	175	160	193	48.1	40.1	58.1
KDL	8.6	4.6	16.1	230	200	307	137	110	163	175	153	204	43.3	40.1	59.6
HDL	12.6	4.8	24.0	183	162	256	118	93	160	138	95	200	40.1	24.0	56.1
EPH	12.8	4.0	16.8	250	160	284	145	85	210	180	125	205	52.1	36.1	86.2
NZP	6.4	5.4	14.8	338	241	406	205	185	265	274	218	290	72.1	64.1	84.2
GKS	5.2	2.2	14.2	204	187	241	128	115	156	155	135	190	40.1	32.1	51.5
KLB	4.8	4.4	5.8	248	224	272	140	140	150	183	170	210	48.1	42.1	50.1
KHT	4.6	2.4	11.8	202	182	262	120	105	145	160	135	205	40.1	38.1	50.1
CKL	6.8	4.4	16.0	256	161	294	155	105	178	200	125	230	58.1	40.1	66.1
EGR	5.2	3.8	17.4	272	198	354	180	133	196	196	155	230	60.1	44.1	80.2
CAM	6.6	4.2	16.2	218	181	288	135	110	171	175	120	215	50.1	36.1	64.1
AGF	5.6	4.2	14.6	230	172	256	149	105	165	185	130	200	52.9	40.1	56.1

Surface waters	Mg (mg L^{-1})			K (mg L^{-1})			Na (mg L^{-1})			Cl (mg L^{-1})			F (mg L^{-1})		
	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.
ADL	13.2	10.6	15.9	1.7	1.2	2.1	12.5	10.2	15.4	21.8	17.7	24.3	0.4	1.2	0.6
BDL	13.4	9.7	14.6	1.6	1.1	2.7	12.0	8.3	15.0	23.7	21.4	29.4	0.1	2.8	0.4
KDL	13.1	11.6	16.4	1.7	1.4	1.8	13.9	9.7	21.4	23.1	16.5	28.4	0.2	1.1	0.6
HDL	11.6	7.3	13.4	5.2	4.6	6.1	12.7	8.8	14.6	21.1	12.1	33.3	0.1	0.7	0.5
EPH	12.2	8.5	20.7	1.7	1.1	1.8	14.2	10.0	20.9	24.1	14.9	29.8	0.2	2.0	0.7
NZP	18.2	13.4	28.0	1.6	1.0	2.6	8.2	6.2	18.6	36.2	13.3	55.3	0.2	1.4	1.0
GKS	13.4	8.5	19.5	0.5	0.4	2.0	3.1	2.1	4.0	15.6	10.4	26.2	0.1	0.8	0.4
KLB	17.0	15.8	20.7	0.8	0.6	0.9	3.7	3.3	4.5	21.3	16.3	24.8	0.2	0.7	0.4
KHT	14.6	9.7	19.5	1.0	0.7	1.5	2.9	2.7	3.8	17.7	9.4	25.5	0.1	0.7	0.5
CKL	13.4	6.1	15.8	0.6	0.1	2.6	3.0	2.0	9.2	17.7	10.1	22.0	0.1	0.8	0.5
EGR	15.2	9.7	19.5	1.4	0.7	2.8	7.4	3.9	12.0	23.5	16.3	49.6	0.1	1.1	0.8
CAM	12.2	7.3	17.0	1.2	0.5	2.0	9.4	7.0	13.4	14.9	13.5	23.4	0.1	1.7	0.5
AGF	12.2	7.3	15.8	1.1	0.7	2.4	4.5	3.6	9.3	17.4	11.1	22.0	0.1	0.8	0.3

Surface waters	SO_4 (mg L^{-1})			NH_3-N (mg L^{-1})			NO_3-N (mg L^{-1})			PO_4-P (µg L^{-1})		
	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.	Med.	Min.	Max.
ADL	33.4	29.7	38.1	0.32	0.14	0.86	3.7	2.1	4.1	22	10	38
BDL	32.8	22.7	38.1	0.30	0.20	0.83	3.9	2.6	5.2	18	10	35
KDL	32.5	26.7	39.0	0.31	0.06	0.87	4.1	2.6	5.5	25	5	35
HDL	23.6	19.6	28.2	0.51	0.16	1.08	4.4	3.0	5.3	65	20	190
EPH	34.4	26.4	38.7	0.31	0.10	0.92	3.6	1.6	5.6	20	10	40
NZP	24.5	8.5	38.1	0.47	0.24	1.40	4.8	1.9	6.1	25	10	50
GKS	23.3	15.9	34.4	0.29	0.10	0.80	4.1	1.9	4.2	25	10	40
KLB	26.7	14.0	33.8	0.33	0.24	0.65	4.5	3.0	5.0	30	10	40
KHT	22.7	16.5	28.2	0.34	0.24	0.58	3.5	1.9	4.2	10	10	10
CKL	15.3	9.7	36.3	0.24	0.10	0.80	3.9	2.3	6.7	40	20	300
EGR	26.4	14.0	44.1	0.41	0.20	1.60	4.0	2.5	5.1	40	30	270
CAM	22.7	14.0	39.9	0.33	0.20	0.51	3.2	2.0	4.9	30	10	40
AGF	21.4	11.0	35.6	0.51	0.29	0.85	3.6	2.2	5.3	20	10	40

running water. However, some properties of HDL and NZP clearly distinguished from all surface waters. Table 2 shows the median-minimum-maximum values of the monitored variables at 13 surface water sources in the

Table 3: Spearman's correlation matrix for environmental variables of investigated surface waters in Southeastern Anatolia of the Lower Euphrates River Basin

Variables	pH	EC	Tur	TSS	TDS	Alk	Hard	Ca	Mg	K	Na	Cl	SO_4	NH_3-N	NO_3-N	PO_4-P
pH	1															
EC	-0.03	1														
Tur	0.83***	-0.41	1													
TSS	0.65*	-0.08	0.67**	1												
TDS	0.00	0.98***	-0.33	0.00	1											
Alk	-0.01	0.92***	-0.36	-0.07	0.93***	1										
Hard	-0.07	0.94***	-0.44	-0.16	0.90***	0.94***	1									
Ca	0.04	0.90***	-0.40	-0.01	0.86***	0.93***	0.96***	1								
Mg	-0.24	0.46	-0.26	-0.57*	0.48	0.44	0.45	0.30	1							
K	0.77**	-0.07	0.73**	0.82***	-0.02	-0.11	-0.21	-0.06	-0.37	1						
Na	0.69**	-0.02	0.63*	0.85***	0.08	-0.02	-0.16	-0.01	-0.45	0.92***	1					
Cl	0.47	0.55*	0.28	0.40	0.63*	0.44	0.36	0.39	0.35	0.57*	0.53*	1				
SO_4	0.56*	0.12	0.55*	0.54*	0.24	0.04	-0.09	-0.04	0.10	0.69**	0.76**	0.72*	1			
NH_3-N	0.22	0.02	0.08	-0.19	-0.08	0.07	0.10	0.14	0.06	0.25	0.01	0.02	-0.16	1		
NO_3-N	-0.03	0.26	-0.01	0.01	0.33	0.16	0.11	0.02	0.24	0.07	0.09	0.43	0.18	0.03	1	
PO_4-P	-0.05	0.14	-0.04	0.00	0.17	0.20	0.17	0.18	0.00	-0.04	-0.04	-0.17	-0.23	0.13	0.35	1

*$p<0.05$ **$p<0.01$ ***$p<0.001$

region. The correlation matrix of the 16 environmental variables revealed high correlations among some of the measured variables (Table 3).

Median pH values of dam lakes and streams were in a narrow range (between 7.9 and 8.2). However, lakes generally displayed slightly higher pH values (8.1-8.2) than streams (7.9-8.0) (Fig. 2a). Contrary to expectation, pH was not correlated with alkalinity, calcium or magnesium. On the other hand it was positively correlated with potassium, sodium, sulfate and turbidity (Table 3), presumably due to their relatively high levels in lakes with higher pH value.

DO values of surface waters were almost saturated when temperature and elevation were taken into consideration (Table 2, Fig. 2b). BOD contents of the all water sources were <1.6 mg L^{-1}, except for HDL (3.9 mg L^{-1}) and EGR (2.3 mg L^{-1}). These higher values might result from exposition of HDL, a small lake, subject to intensive agriculture and of EGR to sewage discharge (Table 2, Fig. 2c). However, DO and BOD were not correlated with the monitored environmental variables and thus they were removed from correlation matrix.

Although turbidity and TSS showed almost uniform distribution among water sources, lakes had higher concentrations than running waters (Table 2, Fig. 2d, e). As one expected, there was a close correlation between turbidity and TSS ($p<0.01$). These variables, moreover were significantly correlated with sodium, potassium and sulfate (Table 3). This close relationship might be due to high turbidity and suspended solids contents of lakes as it was in pH. Similar relationship was however, not observed between other ions such as calcium and magnesium. It had been already recorded that lakes with high turbidity and TSS content had lower calcium and magnesium concentrations than streams. This situation might reflect the effects of soil structure that is main ion source for inland waters.

Median EC values of surface waters changed between 295 and 569 μS cm^{-1} (Table 2, Fig. 2f). Median TDS were between 183 and 338 mg L^{-1} (Table 2, Fig. 2g). The EC values were highly significantly correlated ($p<0.001$) with the TDS (Table 3) because of being a measure of dissolved solids and ionized salts in the waters. Minimum EC and TDS values were measured in HDL which had high suspended solids concentration whilst maximum values were in NZP. In same way, minimum and maximum values for total alkalinity and total hardness, mainly a reflection of major ions e.g., Ca, Mg, CO_3, HCO_3 were determined in these mentioned water sources (Table 2, Fig. 2h, i). Total alkalinity and total hardness also correlated well ($p<0.001$) with EC and TDS (Table 3). Indeed, HDL and NZP displayed the great differences especially in terms TDS and specific ion concentrations.

The concentrations of major ions showed different patterns among lakes and running waters. Bivalent cations (Ca and Mg) varied between 40.1 and 72.1 mg Ca^{+2} L^{-1} and between 11.6 and 18.2 mg Mg^{+2} L^{-1}, respectively (Table 2, Fig. 2j, k). Even if Ca and Mg did not exhibit a clear pattern for lakes and streams, running waters generally had higher concentrations than lakes. Despite being bottom water of ADL and BDL, EPH had higher Ca concentrations and lower Mg concentrations than these lakes. Total dissolved solids contents of the river had already been determined slightly high. Dissolved solids and related variables (EC, Alk and Hard) were highly correlated ($p<0.001$) with Ca but not other ions (Table 3). As it were in dissolved solids and related variables, minimum and maximum concentrations of Ca-Mg were recorded for HDL and NZP, respectively.

Monovalent cations (K and Na) displayed a different pattern compared to divalent cations. While maximum K was determined in HDL as median value of 5.2 mg L^{-1}, median K values ranged between 0.5 and 1.6 mg L^{-1} in the

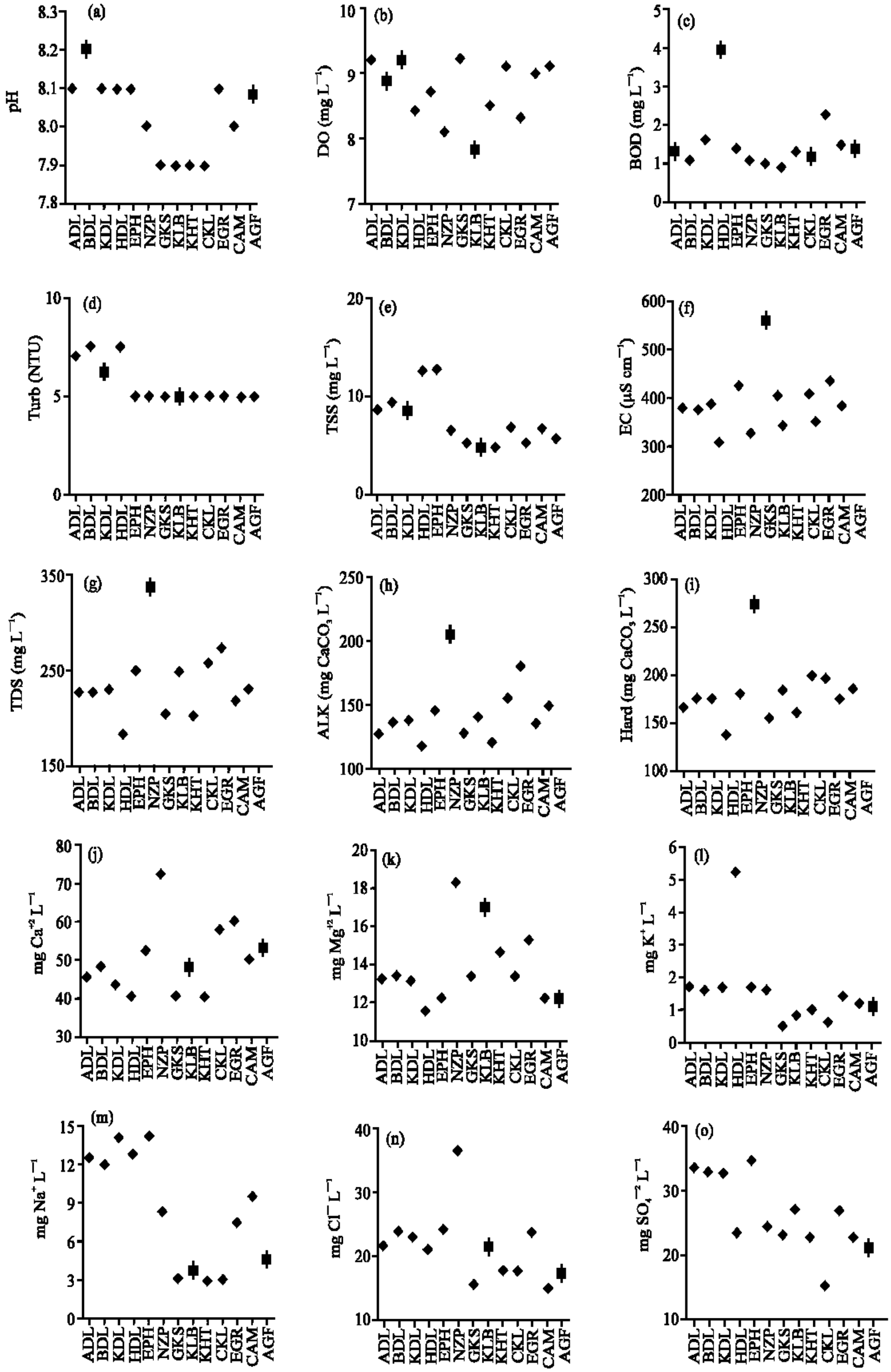

Fig. 2: Continued

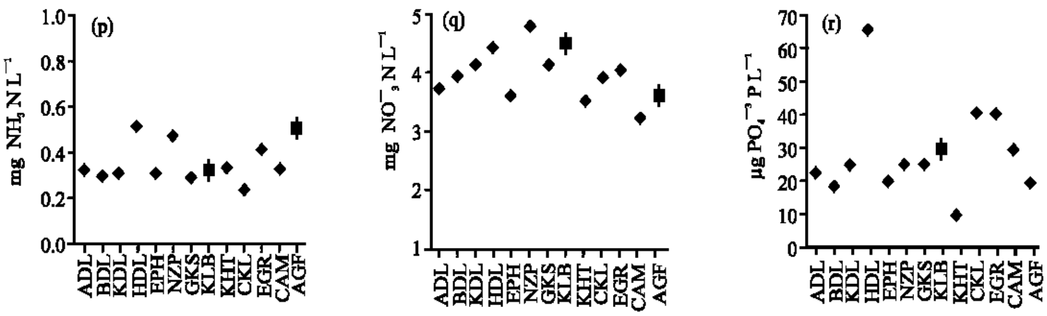

Fig. 2: Trends of selected environmental variables in surface waters of Lower Euphrates River Basin. a) pH, b) dissolved oxygen, c) biochemical oxygen demand, d) turbidity, e) total suspended solids, f) electrical conductivity, g) total dissolved solids, h) total alkalinity, i) total hardness, j) calcium, k) magnesium, l) potassium, m) sodium, n) chloride, o) sulfate, p) ammonia nitrogen, q) nitrate nitrogen, r) reactive phosphorus

other waters. The concentrations of Na for lakes and EPH were found higher than streams (Table 2). K contents of surface waters were more regular compared to distribution of Na content (Fig. 2l and m). A highly significant ($r^2 = 0.92$, $p<0.001$) relationship between K and Na may reflect characteristics of the basin soils. However, high concentrations of sodium in the lakes might result from high content of EPH and dam lakes in upper basin. Extreme values of HDL which is completely surrounded by intensive cotton agriculture area may be related to use of potassium fertilizer an essential nutrient for boll and fiber growth of cotton plant.

Major Sanions monitored (Cl and SO_4) in surface waters showed generally similar trends between lakes and streams (Table 2, Fig. 2n and o). Chloride concentrations of the dam lakes were higher than streams except for NZP. Also, concentrations of EPH were determined slightly higher than dam lakes. It's likely that surface water of dam lakes may be more diluted in point of anions than bottom water. Maximum median of Cl was determined in NZP whilst maximum median of SO_4 in EPH. Contents of monitored major anions of large dam lakes were generally more than those of streams.

Ammonia nitrogen concentrations of surface waters were in a relatively narrow range (0.1 and 0.5 mg L^{-1}) (Table 2, Fig. 2p). Concentrations in large dam lakes were found similar. HDL, NZP and AGF had maximum values of median ammonia. This distribution might reflect effect of pollution on NH_3-N concentration because high concentrations were determined in these surface waters exposed to point and nonpoint domestic and agricultural discharges. Although, AGF is not exposed to large scale pollution, rural discharges including especially livestock might have effects on the monitored lower reach. Similar effects were also observed in EGR and CAM which exposed to agricultural nonpoint and rural point source discharge. Distribution of NO_3-N and PO_4-P concentrations also supported this view because of displaying similar trends to ammonia. NO_3-N was recorded between 3.2 and 4.8 mg L^{-1} in all surface waters and maximum values were observed in HDL and NZP (Table 2, Fig. 2q).

An ascending trend in NO_3-N and PO_4-P originated from effects of discharges in KLB was observed. The concentrations of PO_4-P of the surface waters in the region changed between 10 and 65 µg L^{-1} and maximum concentration of median values was recorded in HDL (Table 2, Fig. 2r). Egri and CKL, exposed to point sewage discharge, displayed similar values. KDL, the last dam of EPH almost completely surrounded by agriculture area, had the highest NO_3-N and PO_4-P concentrations amongst large dam lakes.

Although Total Phosphorus (TP) concentrations were not determined in this study it is expected that TP would be slightly higher than PO_4-P content. When PO_4-P concentrations are taken into account, trophic status of large dam lakes (ADL, BDL and KDL) seem to be mesotrophic and trophic status of HDL seem to be eutrophic. Similarly, in terms of NO_3-N dam lakes in the region seem to be eutrophic. Thus, it could be concluded that primer production of large dam lakes in the region is limited by phosphorus as is it case in most of the inland surface waters (Harris, 1986).

DISCUSSION

There are limited numbers of studies on water quality of surface waters of the region. Moreover, existing studies include only ADL and they are generally based on technical reports of official institutions. Just one study on EGR and GKS amongst running waters was found. General Directorate of Electrical Power Resources Survey and Development Administration of Turkey (EIE, 1996) which is charged to research the water sources for producing electrical energy and make hydrological and geotechnical studies has a wide stream monitoring network. Although they are screening many streams in the Upper and Middle Euphrates Basin, monitoring studies on running waters of lower basin do not include water quality data except for GKS.

Although values of major ions (Ca, Mg, Na, K, Cl, SO_4) and related variables (EC, TDS, Alk, Hard) in the research were generally slightly lower than those of existing technical reports on ADL (COB, 2004a). While NO_3-N concentrations of the present study were determined a little bit higher than findings of other studies, PO_4-P concentrations were less.

pH values and SO_4 concentrations of a study by Atasoy and Senes (2004) in ADL were slightly less whilst EC, DO, NH_3-N and NO_3-N were higher than results of the study. pH values of a study with limited number of variables including pH, DO, BOD and COD on EGR were higher (median 8.4) than the results (median 8.1). Median value of total hardness (155 mg $CaCO_3$ L^{-1}) and pH (7.9) of GKS in the study showed similarity with results (155 mg $CaCO_3$ L^{-1} and 8.0, respectively) of EIE (1996). Amounts of Cl (15.6 mg L^{-1}), SO_4 (23.3 mg L^{-1}) and EC (320 μS cm^{-1}) in the study were determined higher than EIE (1996)'s records (7.8 mg L^{-1}, 17.3 mg L^{-1} and 287 μS cm^{-1}, respectively) but K (0.5 mg L^{-1}), Na (3.1 mg L^{-1}) and Ca+Mg (1.6 meq L^{-1}) were less (1.2 mg L^{-1}, 3.8 mg L^{-1} and 2.8 meq L^{-1}, respectively).

PCA revealed two main directions of variation, with axis 1 explaining 40.6% of the total variance and axis 2 explaining an additional 27.0% (Fig. 3). An examination of the inter-set correlations of environmental variables, together with the position and length of the arrows, revealed that the strongest direction of variation (PC1) was primarily a gradient of major ions and related variables consisting of Ca, Mg, EC, TDS, Alk and Hard. The second gradient (PC2) was characterized by correlations to pH, Turb, TSS, SO_4, K, Na and nutrients. These variables had generally high positive correlations with PCA axis 2 and to each other and plotted towards the right of the ordination. PCA also clearly separated the characters of surface waters with dam lakes and river plotting exclusively on the right hand side of the ordination indicating that these surface waters were characterized by higher concentrations of K, Na and nutrients. NZP, KLB, CKL, EGR and AGF with higher hardness, on the other hand, plotted on the left hand side of the ordination and were associated with high Ca, Mg and TDS content and related variables containing EC, Alk and Hard. While EPH and its main dams plotted at very close with similar water quality characteristics, NZP with highest dissolved solids content separately plotted among all surface waters.

While pH and EC values of EPH were similar to values of its main reaches (Karasu and Murat Rivers) in upper basin, other variables (Hard, Ca, Mg, K, Na, Cl, SO_4) were generally less than EIE (1996)'s results. Also, contents of ions and nutrients and pH value of Keban Dam lake, first dam of EPH were generally lower than other dams on the river. Nevertheless, Karakaya Dam lake, second dam of Euphrates River located below Keban Dam and above Ataturk Dam, displayed more similar properties to dams of lower basin rather than Keban Dam in terms of ions and nutrient phosphorus (Table 2 and 4).

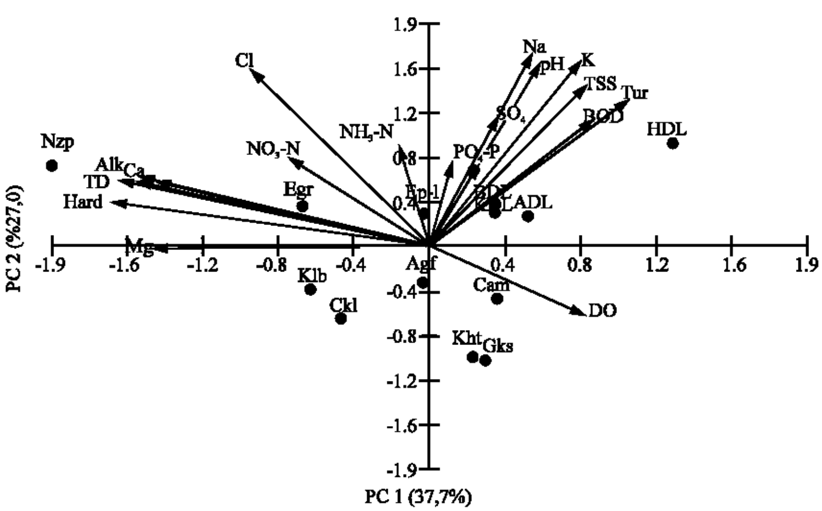

Fig. 3: Principal components analysis of the surface waters and environmental variables

Table 4: Water quality characteristics of large dam lakes and some of major running waters of Upper and Middle Euphrates River Basin (from DSI, 1982, 1994; EIE, 1996; TKB, 2004)

Characteristics	Keban	Karakaya	Murat	Karasu
pH	7.50	7.90	8.0	8.1
EC (μS cm^{-1})	240.00	306.00	419.0	499.0
Turb (NTU)	3.00	3.00	-	-
TSS (mg L^{-1})	5.00	7.00	-	-
TDS (mg L^{-1})	120.00	170.00	-	-
Alk (mg $CaCO_3$ L^{-1})	148.00	130.00	-	-
Hard (mg $CaCO_3$ L^{-1})	170.00	160.00	151.0	208.0
Ca (mg L^{-1})	32.10	40.10	-	-
Mg (mg L^{-1})	19.50	14.50	-	-
K (mg L^{-1})	-	-	3.1	1.6
Na (mg L^{-1})	-	-	31.2	25.2
Cl (mg L^{-1})	39.60	40.00	38.5	32.7
SO_4 (mg L^{-1})	41.00	31.00	43.0	63.0
NH_3-N (mg L^{-1})	0.02	0.05	-	-
NO_3-N (mg L^{-1})	0.40	0.80	-	-
PO_4-P (μg L^{-1})	10.00	20.00	-	-
Ca+Mg (meq L^{-1})	-	-	3.0	4.2

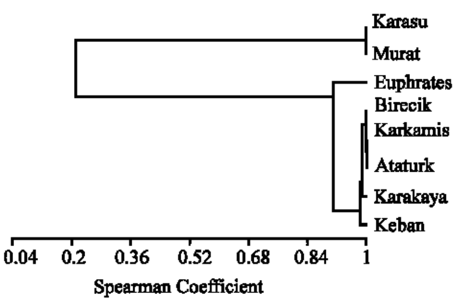

Fig. 4: Dendrogram from cluster with the use of water quality data as input variables

The cluster analyses of existing water quality data (Table 2 and 4) distributed into two main groups (Fig. 4): Euphrates River together with its dam lakes and Euphrates River's main tributaries. Karasu and Murat Rivers, longest flowing part of the Euphrates as a result of almost entirely being turned into dam lakes showed running water properties with high ion concentrations. Dam lakes of the lower basin (Ataturk, Birecik and Karkamis) with alkaline-hard water were separated from dam lakes of upper/middle basin (Keban and Karakaya) with more diluted ions and nutrient contents. Water chemistry of Ataturk and Karkamis Dam lakes were more similar to each other in comparison to Birecik Dam lake. As expected, Euphrates River also reflected water chemistry properties of dam lakes. Cluster analysis showed that dam lakes in all basin and Euphrates River displayed very similar characteristics. Water chemistry of Karakaya Dam lake showed transition properties between Keban Dam in Upper Basin and Ataturk Dam in Lower Basin. In addition, Euphrates River was less similar to main tributaries rather than dam lakes and it mainly reflected water chemistry properties of dam lakes. This study shows that calcium is main dissolved ion in region's surface waters due to nature of bedrock geology. In addition to bedrock structure, agricultural practices such as excessive irrigation and fertilization effects surface water chemistry. It is true that excessive irrigation is today a serious problem in the region and soils are getting hyper-saline. This case can be contributing to dissolved ions concentrations of reservoirs. High nitrate loads of surface waters monitored probably result from excessive fertilizer use in the region land approximately 75% of which is cultivated. Although domestic and industrial discharges seem to be polluting the some sources they do not lead to large scale pollution in comparison to nonpoint agricultural discharge.

CONCLUSION

Naturally, dam lakes in upper basin greatly affect the water chemistry of dam lakes of the Lower Euphrates Basin. Furthermore, water chemistry of Euphrates River fed from bottom water of the dam lakes reflects properties of these lakes.

Today, dam lakes and streams display mesotrophy characteristics with regard to nutrient loads but widespread algal blooms cases that do not augur well for the future have been recently recorded in Ataturk Dam lake. If point and nonpoint discharge continue at today's density, rapid eutrophication will be inevitable especially in dam lakes. Dam lakes in the region are also used as drinking water source and this case can create a public health risk in the near future.

ACKNOWLEDGEMENTS

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