Evaluation of Water Quality Monitoring Networks Using Principal Component Analysis: A case of Gediz River Basin

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Abstract
The water quality needs to be monitored at regular intervals, throughout representatively located gauging stations, for sustainable development of water resources. However, it is not possible to monitor all quality parameters all the time and points for a river basin studied, and water quality monitoring that does not address specific, clear and realistic objectives will cause time, labor and money losses. At this point, Principal Component Analysis (PCA) would provide a regional insight into principal pollutants, contaminants dominates others and effective monitoring locations. It will help to evaluate surface water quality in regional scale as well as monitoring network. This study aims to analyze regional water quality and monitoring network in the Gediz River Basin, by focusing on the variance structure of the observations on principal pollutants that observed throughout the river basin. The 11 quality parameters monitored in 13 monitoring stations on the Gediz River Basin were used in the analyses. PCA is applied i) to determine principal pollutants and contaminants dominate over others (parameter-based analysis), ii) to find out effective monitoring locations for principal pollutants (station based analysis). The results reveal the tributaries of the river with different quality characteristics, and the importance of an objective based monitoring for effective water quality management.
Keywords: principal component analysis; monitoring networks; water quality; Gediz River

1. Introduction

Monitoring water quality is important not only to preserve limited available fresh water for various uses but also to control its impact on public health [1]. Water quality is degenerated in river basins mainly by anthropogenic factors, in the forms of physical, chemical, biological and radioactive pollution. This degeneration is created by artificial/natural land based contaminants in lands, leaks or seas as well as by particulate matters, radioactive contaminants and some industrial gases in the atmosphere. Vega et al., Reisenhofer et al. and Ahmad et al. define stream discharge as a major source of change in water quality [2,3,4], while Huang and Foo stress that engineering and management modifications in a river system affect the water quality characteristics of the river [5].

Water quality requirements greatly depend on usage. For instance, drinking water has to be purified completely from pathogens, toxics, and carcinogenic contaminants, and to satisfy some other water quality criteria, as well as some physical properties such as flavor, odour, temperature etc. [6]. Preliminary quality criteria for irrigation water are concentrations of dissolvable salts, toxic elements, calcium, magnesium, bicarbonate and the sodium/cation ratios [7]. For energy production, suspended sediment concentration is the main factor [8], while physical parameters are main concerns for recreational and industrial usages. This complexity is getting more remarkable on river basin scale, such that monitoring and evaluating all these quality parameters through various flow sections is a quite complicated process that needs consideration of different kinds of contaminants, different location, different time and different water usages altogether.

Such a variant structure of surface water quality require spatio-temporal quality monitoring, followed by a complex data interpretation of a large data matrix, consist of physicochemical parameters [9]. During the last decades, multivariate statistical methods have been applied to environmental systems [10]. Benefits of reducing pertinent environmental parameters by exploratory statistical analyses have been emphasized in the literature [11,12]. Multi statistical analyses elucidate the spatio-temporal behavior and variation of water quality along studied ecological systems. It is a valuable tool for water resources management and provides rapid solutions to water quality problems via summary statistics [1,13]. Principal component analysis (PCA), at this point, is a special promise for furnishing new and unique insights into the interactions in a wide range of pollution and eco-toxicological situations [14,15]. PCA allows better understanding of water quality and ecological status, identifying possible factors/sources on the problem and interpreting complex data matrices [16]. It has been applied to various environmental issues, including ground water levels, hydrographs, and surface water contamination [17].

This paper aims to provide a scientific background and an expertise to the local stakeholders, on regional water quality and monitoring network for the Gediz River Basin. Following the primarily basic statistical analyses, parameter based analysis (PBA) is conducted to determine principal pollutants and contaminants on the basin, and station based analysis (SBA) is conducted to get effective monitoring locations for the principal pollutants. Results of the analyses have identified regional river water quality, principal pollutants and essential stations for monitoring. A discussion has been held to identify river segments with different water quality and to evaluate the water quality monitoring network, based on the gauging locations as well as on the parameters measured.

2. Materials and Methods

2.1 Study Area

The Gediz River Basin is located in the middle of Aegean region, between 38° 01′ - 39° 13′ northern latitude and 26° 42′ - 29° 45′ southern longitude. The drainage area of the basin is approximately 17 220 km^2. The cumulative annual precipitation, water potential and mean flow are 600 mm, 2.76 km^3/year and 73.2 m^3/s, respectively [19]. Surface water of the basin discharges into the Aegean Sea via the Gediz River and its tributaries (Figure 1).

Gediz delta, one of the fourteen RAMSAR site in Turkey, is designated as a cultural and natural asset and wildlife protection area in 1994. Since it is becoming significantly polluted, water quality issues have great importance for breeding, feeding, wintering and sheltering of numerous species of waterbirds.

Marmara Lake and Demirkopru Dam are the most important reservoirs that affect the river system in terms of water quality and quantity. Marmara Lake supplies irrigation water to the right side of the Gediz Basin. Golcuk, Karagol and Sazligol are the other natural lakes in the basin. Buldan and Avsar irrigation dams are the other reservoirs in the basin. High agricultural potential and developing industry result in rapid increase in the population, therefore excessive use of fertilizers and chemical substances, degrading the water quality [19]. Pollutants in the basin can be grouped into three categories by their sources. These are sourced from i) Domestic wastes to be purified by biological treatment; ii) Industrial wastes that needs special treatment process due to their chemical compositions; iii)Agricultural wastes generated by fertilizers and chemical substances [19]. All wastewater of Manisa province, Kemalpasa Industrial region and Akhisar village are discharged into the Gediz River. Thought the upper reaches of the river can still be used for irrigational and drinking purposes, water pollution in the river is alarming. Water quality measurements in the Gediz River are made in 2, 4 and 6 months intervals, by State Hydraulics Works (DSI) and General Directorate of Electrical Power Resources Survey and Development Administration (EIE). It should be noted that all management facilities of water quality monitoring stations (WMSs) were transferred to DSI in 2012. Main parameters monitored are As, BOD_5, Ca, Cd, Cl, Cr, DO, E-Coli, EC, Hg, Na, $NH_{3\text{-}N}$, $NO_{2\text{-}N}$, $NO_{3\text{-}N}$, Pb, pH, SS and T-Coli.

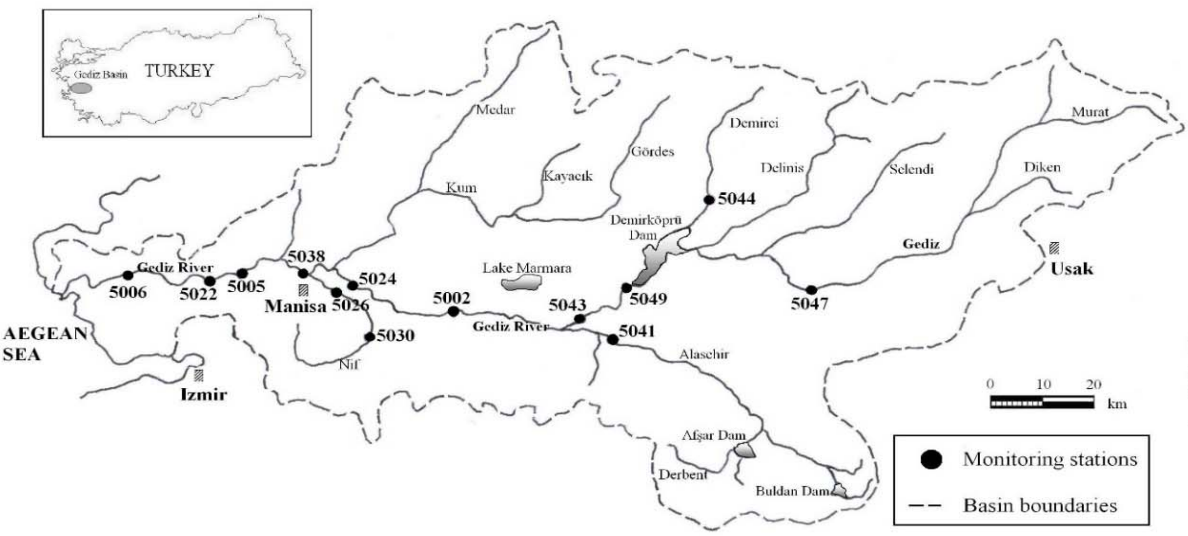

Figure 1. Gediz River Basin and the WMS considered in the study.

2.2 Data

After analysis of the available data regarding homogeneity and consistency, 11 quality parameters (BOD_5, Ca, Cl, DO, EC, Na, $NH_{3\text{-}N}$, $NO_{2\text{-}N}$, $NO_{3\text{-}N}$, pH, SS) and the records of 13 quality monitoring stations are taken into consideration for the time period of 1991 to 2000. Some suspect observations were tested by simple time series depiction and subsequent outlier analysis. Inaccurate data were removed. Missing observations were completed considering the average of bimonthly observations and the records of the upstream stations. Basic statistics are given in Table 1, where the bold numbers designate the critical values (see Section 2.3).

Table 1. Summary statistics of quality parameters monitored in the Gediz River

Station	Stat.	BOD_5 (mg/l)	DO (mg/l)	Ca (mg/l)	Na (mg/l)	Cl (mg/l)	EC (mho/cm)	NH_3-N (mg/l)	NO_2-N (mg/l)	NO_3-N (mg/l)	pH	SS (mg/l)
5006	Min.	0.60	**2.00**	34.80	9.20	14.700	276.000	0.000	0.000	0.000	7.200	1.000
	Max.	21.70	14.50	107.00	137.54	147.472	1603.000	0.020	0.806	4.720	9.600	82.000
	Mean	4.141	6.35	57.25	66.65	64.449	826.234	0.004	0.034	0.864	8.262	23.414
	Stdev.	2.89	2.34	13.68	36.23	33.071	327.413	0.006	0.104	0.980	0.636	17.441
5022	Min.	1.00	**1.00**	24.00	8.05	16.800	317.000	0.000	0.000	0.000	7.100	1.000
	Max.	26.20	12.00	99.40	175.49	156.600	1748.000	0.040	0.848	4.180	9.600	220.000
	Mean	6.56	6.244	58.17	68.19	69.903	865.213	0.004	**0.061**	1.061	8.106	33.781
	Stdev.	4.78	1.73	17.01	41.59	33.801	300.823	0.007	0.135	1.024	0.625	49.094
5005	Min.	1.00	**1.00**	22.00	7.82	16.100	270.000	0.000	0.000	0.000	7.000	2.000
	Max.	60.00	10.60	99.20	327.06	357.300	2300.000	0.230	0.697	2.960	9.900	696.000
	Mean	11.12	5.26	59.07	84.20	80.255	932.150	0.008	0.034	0.598	7.978	51.215
	Stdev.	10.76	2.52	17.52	59.51	55.069	403.941	0.030	0.093	0.716	0.611	96.889
5038	Min.	0.30	3.60	27.60	5.98	15.400	347.000	0.000	0.000	0.000	7.500	1.000
	Max.	18.00	13.30	101.60	113.39	102.200	1455.000	0.040	0.100	2.640	9.800	209.000
	Mean	3.98	7.82	54.24	53.41	51.965	778.046	0.006	0.013	0.670	8.405	36.019
	Stdev.	3.05	1.89	15.30	30.15	21.295	256.666	0.008	0.015	0.623	0.563	44.478
5026	Min.	1.00	3.00	18.60	6.90	13.300	346.000	0.000	0.000	0.000	7.200	1.000
	Max.	90.00	13.29	98.60	209.30	244.900	2000.000	0.150	0.220	7.846	9.200	**1439.000**
	Mean	7.11	7.14	59.94	74.68	93.510	901.733	0.007	0.024	2.255	**7.940**	**97.618**
	Stdev.	11.74	2.17	15.36	47.93	52.210	334.342	0.020	0.032	1.965	0.463	213.691
5030	Min.	0.40	**0.80**	18.20	6.44	15.750	477.000	0.000	0.000	0.000	6.900	1.000
	Max.	**330.00**	11.50	160.00	889.64	**889.800**	**5760.000**	2.010	0.560	10.980	9.100	339.000
	Mean	**27.25**	5.06	79.63	**210.01**	234.405	**1713.133**	0.081	**0.077**	2.368	**7.805**	44.569
	Stdev.	50.87	2.39	31.75	189.13	175.930	1095.098	0.266	0.128	2.637	0.533	68.038
5024	Min.	1.00	5.03	23.00	17.02	21.600	374.000	0.000	0.000	0.000	7.400	1.000
	Max.	18.70	12.31	96.00	**159.39**	134.400	1470.000	0.040	0.080	10.700	10.000	248.000
	Mean	4.65	8.30	54.13	60.05	54.252	815.491	0.003	0.014	0.994	8.370	43.760
	Stdev.	2.85	1.60	16.18	30.01	24.383	**256.152**	0.006	0.013	1.476	0.550	49.389
5002	Min.	0.70	3.96	25.40	4.60	20.600	328.000	0.000	0.000	0.000	7.100	1.000
	Max.	20.00	12.20	86.40	**138.69**	189.300	1681.000	0.070	0.506	4.410	9.200	232.000
	Mean	4.46	7.91	54.26	60.49	56.304	808.042	0.005	0.035	1.031	8.191	24.602
	Stdev.	2.64	1.56	12.10	31.93	29.109	**264.252**	0.010	0.075	0.963	0.440	33.905
5041	Min.	0.100	3.40	22.00	5.98	13.300	202.000	0.000	0.000	0.000	7.300	1.000
	Max.	15.00	13.10	100.0	**140.50**	104.300	1912.000	0.090	0.170	4.270	9.600	178.000
	Mean	4.63	7.37	52.42	63.28	**40.548**	799.749	0.008	**0.020**	0.554	8.245	33.894
	Stdev.	2.84	2.05	18.34	43.48	19.169	444.989	0.016	0.025	0.818	0.504	37.782
5043	Min.	0.50	4.97	32.80	3.68	15.050	9.800	0.000	0.000	0.000	7.500	1.000
	Max.	13.70	12.50	78.40	**103.96**	92.500	1540.000	0.020	0.280	2.560	9.200	140.000
	Mean	**3.59**	8.57	56.44	**39.13**	43.119	825.645	0.004	**0.020**	0.206	8.244	18.562
	Stdev.	1.93	1.40	11.95	20.34	16.513	**241.970**	0.006	0.038	0.379	0.380	28.897
5049	Min.	0.40	5.65	16.80	6.21	13.300	314.000	0.000	0.000	0.000	7.000	0.000
	Max.	7.70	11.80	93.80	**88.09**	95.700	1056.000	0.020	0.090	2.030	9.200	92.000
	Mean	**2.95**	8.46	55.66	32.18	**30.911**	673.333	0.001	**0.010**	0.188	8.100	9.440
	Stdev.	1.50	1.29	13.27	18.66	12.637	**138.400**	0.004	0.014	0.353	0.470	14.150
5044	Min.	0.41	4.60	18.00	6.40	12.250	199.000	0.000	0.000	0.000	6.800	0.000
	Max.	15.0	16.40	120.6	**170.43**	265.000	1604.000	0.020	0.172	3.680	9.000	193.000

	Mean	**3.46**	8.95	56.14	52.01	**37.757**	782.506	0.001	**0.014**	0.459	8.099	**30.980**
	Stdev.	2.09	2.49	19.52	33.13	32.156	322.823	0.004	0.023	0.675	0.391	34.662
5047	Min.	0.40	6.07	26.40	7.13	15.400	357.000	0.000	0.000	0.000	7.200	1.000
	Max.	7.00	13.00	99.60	**122.36**	102.000	1495.000	0.030	0.073	1.400	9.700	288.000
	Mean	**3.54**	9.14	60.79	38.55	**31.668**	851.909	0.006	**0.017**	0.289	8.159	**43.941**
	Stdev.	1.58	1.73	13.58	23.48	14.338	**220.588**	0.008	0.013	0.305	0.437	58.441

2.3 Water Quality Criteria

There are many definitions in the literature for the water quality criteria. This study employs the criteria given by the Ministry of Forestry and Water Works for surface water resources [8]. Water quality classes claimed by MoFW are given in Table 2, in which Class I designates high quality waters to be used for drinking purpose after disinfection, and for recreational, agricultural, livestock purposes, directly; Class II designates slightly polluted waters to be used for drinking purpose after an advanced or suitable purification procedure, and for recreational, agricultural, livestock purposes directly except some fishing activities; Class III designates polluted waters to be used for industrial purposes except the industries requiring high quality water such as textile ad food industries; and Class IV designates waters too polluted.

Table 2. Water quality classes [8]

		Quality classes	DO (mg/l)	NH_{3-N} [a] (mg/l)	NO_{2-N} (mg/l)	NO_{3-N} (mg/l)	Na (mg/l)	pH	BOD_5 (mg/l)	Cl (mg/l)	EC (mho/cm)	SAR	TSC (mg/l)	NO_3^- or NH_4^+ (mg/l)	SS (mg/l)
Inland water	**I**	**high quality**	>8	0.2[a]	0.002	<3	125	6-9	<4	25					
	II	**slightly polluted**	6	1.0[a]	0.01	10	125	6-9	8	200					
	III	**polluted**	3	2.0[a]	0.05	20	250	6-9	20	400					
	IV	**too polluted**	<3	>2.0[a]	>0.05	>20	>250	6-9	>20	>400					
Irrigation	**I**	**excellent**						6.5-8.5	0-25	0-142	0-250	<10	0-175	0-5	20
	II	**good**						6.5-8.5	25-50	142-249	250-750	10-18	175-525	5-10	30
	III	**permissible**						6.5-8.5	50-100	249-426	750-2000	18-26	525-1400	10-30	45
	IV	**doubtful**						6.5-9.0	100-200	426-710	2000-3000	>26	1400-2100	30-50	60
	V	**unsuitable**						<6.0-9.0<	>200	>710	>3000		>2100	>50	>100

[a] when irrigating the plants sensitive to chlorine , these limits can be reduced

2.4 The Multivariate Analysis

Water quality analyses necessities long and consistent monitoring of wide range of water quality parameters. It is not possible to handle such kind of diverse and large data set [20]. Many times, some of these parameters are correlated with each other. Thinking a quality process as a linear combination of n random variables, the explanation of variance structure of the pollution in the basin can be facilitated [11].

The principal components (PCs), algebraically are particular linear combinations of n random variables X1, X2,…,Xn. These combinations geometrically represent the new coordinate system, which corresponds maximum variability axes obtained by rotating the original axes [11] and founded by $\mathbf{Y_i} = \mathbf{l_i'}\,\mathbf{X} = l_{i1}X_1+l_{i2}X_2+\ldots+l_{in}X_n$ that maximizes $Var(Y_i)=\mathbf{l_i'}\,\Sigma\,\mathbf{l_i}$, subject to $\mathbf{l_i'}\,\mathbf{l_i}=1$ and $Cov\,(Y_iY_k)=0$ where $\mathbf{l_i}$'s are loadings of X_i variables, Σ is either the covariance or correlation matrices of $X_1, X_2,\ldots,X_p$ variables. $Var(Y_i)$ and Cov (Y_iY_k) are the variance of i th PC and covariance between i th and k th PCs, respectively. Principal components for a matrix associated with random quality parameter vector $\mathbf{X'} = [X_1, X_2,\ldots,X_n]$, are calculated by Eq. 1, where eigenvalues λ_i determine the variance and eigenvectors e_i determine the maximum variability direction [11].

$$Y_i = \mathbf{e_i'}\,\mathbf{X} = e_{i1}X_1+e_{i2}X_2+\ldots+e_{in}X_n \quad \textbf{(1)}$$

The explained variances %Var(Yi) by each principal component are given by Eq. 2.

$$\%Var(Yi) = \lambda_i/(\lambda_1+\lambda_2+\ldots+\lambda_n) \quad i=1,2,\ldots,n \quad \textbf{(2)}$$

Since the quality parameters are of different size and scales changing in wide ranges, the quality parameters considered have been standardized before obtaining the principal components. This means that correlation matrix has been used in calculations.

In the scope of the study, Principal Component Analyses are applied in two bases. First, PCA is applied to the observations of the quality parameters for each station (parameter based analysis, PBA). This analysis is implemented to reveal principal pollutants and contaminants dominate to others. Second, PCA was applied to the observations in all stations for each quality parameter (station based analysis, SBA). This analysis is conducted to reveal effective monitoring locations for principal pollutants. Calculated correlation matrix, explained variance ratios and correlation coefficients between quality parameters and PCs are given in Table 3 and Table 4.

3. Results and Discussion

3.1 Basic statistics

Basic statistics of water quality parameters (Table 1) reflect regional behavior of Gediz river water quality. The five-day biological oxygen demand (BOD_5) goes beyond the limits (Table 2) for the station 5030, by the effects of the wastewater of Kemalpasa industrial district. Same behavior is also observed for both the maximum statistic and the standard deviation. BOD_5 values of the stations 5043 and 5049 are seen as regulated by Demirkopru Dam.

The minimum dissolved oxygen (DO) of the station 5030, located on the downstream of the industrial district, and the minimum dissolved oxygen of the stations 5005, 5022, 5006, located in the lower basin, are below the limits for aquatic life. However, the mean statistics increase on the upstream of the basin, except the station 5030 (Table 1, Table2, Figure 1). Calcium (Ca) observations are consistent for all statistics --maximum, mean, and standard deviation-- along the river course, except for the maximum statistics of the station 5030. High calcium concentration of the station 5030 affects the total salt concentration (TSC) in an increasing way.

The maximum statistic of the sodium (Na) observations is of an extreme behavior for the stations 5030 and 5024. As another important issue, the mean statistic of Na in the station 5030 is close to the unusable limit (Table 2). On contrary, the maximum statistics are in the first quality class especially for upper-basin stations such as 5047, 5049, 5044 and 5043 where are no industrial contaminants. The standard deviation of Na is so high for the station 5030 and almost equal to the mean statistic. That can be explained with variation of flow rates or seasonal industrial effects. The mean chlorine (Cl) concentration in the river move generally around the second quality water class. It is close to Class I for the stations 5041, 5049, 5044 and 5047. The maximum chlorine concentration is extremely high for the station 5030. The mean electrical conductivity (EC) of the river change around the Class I and II. The total salt concentration is over unsuitable limit for the station 5030. The standard deviations of EC of the stations 5043, 5049, 5047, 5002, 5024 are very low, compared to the mean statistics. This can be explained by uniform industrial discharge and/or by regulatory effects of the Demirkopru Dam.

Of the nitrogen based quality parameters, ammonium ($NH_{3\text{-}N}$) observations on all stations are inside the limits of the first class water quality (Table 1, Table 2). Nitrite ($NO_{2\text{-}N}$) concentrations of the stations 5026 and 5030 corresponds to the Class IV waters, due to the Kemalpasa, Manisa, Akhisar waste water effects. Contrary, Nitrite ($NO_{2\text{-}N}$) concentrations of the stations 5043, 5041, 5049, 5044 and 5047 are within the limits of the Class II waters. The maximum statistics of $NO_{2\text{-}N}$ concentrations are high. The mean statistics of nitrate ($NO_{3\text{-}N}$) of almost all stations are within the limits of the Class I, while the maximum statistics are in Class II. The mean statistics of pH observations are lower in the stations 5026 and 5030 than the others, because while these stations are exposed to high industrial wastewater discharges, the others are subject to salty drainage water of irrigation.

Although basic statistics of quality parameters give us an idea about the behavior of the contamination through the river basin, the advantage of PCA would reveal principal pollutants and stations needs to be monitored for an effective pollution control.

3.2 Parameter Based Analysis

Parameter Based Analysis was implemented to determine the quality parameters defining the river pollution in a considered station. A preliminary analysis was conducted to find correlated parameters. Student t statistic (degree of freedom is N-2, where N is the number of observations) is used to check the hypothesis H_0: $\rho_{x,y} \neq 0$ (i.e. if the correlation coefficient between parameter X and Y is significantly different than zero). PCs were obtained by Eq. (1). Both significant correlation coefficients and obtained principal components are given in Table 3, where bold numbers shows the significant loadings for relevant parameters, and last two columns designate explained variances by each PC and their cumulatives. The following evaluations base on the results in Table 3.

For the stations 5006, 5022, 5005 and 5038, located in the lower basin, almost all contaminants are clearly effective on the low quality. High correlations between the Na, Cl, EC, and BOD_5 are remarkable. Since these stations are at the outlet of the river thus highly polluted, it is not easy to get PCs defining specific type of pollution. The station 5006 is closed to Aegean Sea and at the outlet of the basin. High correlation coefficients between Na, Cl, Ca and EC imply us the existence of sodium and calcium salts. This situation can be seen from the first PC so that it may be called as the salinity or alkalinity component. The second PC may be named as an organic contamination component; however DO is high due to some other influents. The third represents anaerobic conditions. The last one may be interpreted as a component of purification of the organic contaminants including nitrification and salinity of calcium such as $CaOH_2$ that cause decrease in pH.

For the station 5022, the first principal component designate the salinity or alkalinity of the water that can be predicted by the correlation coefficients between Ca, Na, Cl and EC. The second PC may be defined as an organic purification component. The last component shows the contamination based on nitrification. For the station 5005, the first PC may express the suitability of the water for alkalinity; the second one is a component related to organic purification; the third indicate a nitrogen based or agricultural contamination; the last PC may be used to define de-nitrification process starting the settlement of the organic sediments. Considering the correlations and the component loadings of the PC of the station 5038, one can make the following comments on the PC's. The first component represents the alkalinity or salinity, the second one represents the industrial contaminants; the third one may be use to define a nitrogen based or agricultural purification including other specific contamination sources; the last PC may be used as an indicator of de-nitrification process. The stations above have a similar behavior on water quilty. In fact, they are on the main arm of the river, and the variance structures of them can be explained by the first 3 or 4 components.

Table 3. Parameter based principal component analyses

Correlations			**Principal Loadings**												
Parameters	r_{x_i,x_j}	**i**	**BOD_5**	**Ca**	**Cl**	**DO**	**EC**	**Na**	**NH_3-N**	**NO_2-N**	**NO_3-N**	**pH**	**SS**	**Variance (%)**	**T. variance (%)**
Station 5006															
Na-Cl	0.858	1	-0.139	**-0.420**	**-0.472**	0.117	**-0.463**	**-0.450**	0.048	-0.100	-0.266	0.244	0.096	0.334	0.334
EC-Cl	0.811	2	**0.403**	0.005	-0.094	**0.645**	-0.031	-0.162	**0.423**	0.013	0.283	**-0.347**	-0.082	0.145	0.480
Na-EC	0.739	3	**-0.552**	0.094	-0.108	-0.072	0.034	-0.095	**0.346**	0.254	0.084	-0.041	**-0.683**	0.118	0.598
Cl-Ca	0.666	4	-0.268	**0.301**	-0.184	0.052	-0.105	-0.119	**-0.366**	**-0.668**	0.192	**-0.388**	-0.094	0.104	0.701
EC-Ca	0.653														
Station 5022															
EC-Ca	0.812	1	0.240	**0.439**	**0.439**	-0.163	**0.472**	**0.397**	0.103	0.072	0.101	-0.161	**-0.311**	0.347	0.347
EC-Cl	0.777	2	**-0.379**	-0.002	0.223	**-0.322**	0.087	0.290	-0.230	0.038	**-0.529**	**0.489**	0.196	0.156	0.504
Na-Cl	0.772	3	0.244	-0.011	0.056	**-0.350**	0.009	0.009	**-0.354**	**-0.682**	**0.384**	0.130	0.244	0.112	0.616
Na-EC	0.765														
Cl-Ca	0.671														
Station 5005															
Na-EC	0.884	1	**-0.404**	**-0.368**	**-0.451**	0.165	**-0.466**	**-0.448**	-0.084	-0.052	0.044	0.164	0.123	0.365	0.365
Na-Cl	0.847	2	-0.080	-0.214	0.081	**-0.349**	0.027	0.154	-0.012	0.004	**-0.652**	**0.605**	-0.052	0.135	0.500
EC-Cl	0.809	3	-0.179	-0.100	-0.008	**-0.478**	-0.005	-0.024	**0.498**	**0.379**	-0.010	-0.287	**0.505**	0.110	0.609
Cl-BOD_5	0.722	4	-0.012	0.152	-0.148	-0.071	-0.063	-0.127	**0.678**	**-0.570**	-0.133	-0.091	**-0.346**	0.097	0.706
EC-Ca	0.679														
Station 5038															
EC-Cl	0.728	1	0.071	**0.382**	**0.505**	0.095	**0.534**	**0.470**	0.233	0.071	0.052	0.045	-0.127	0.254	0.254
Na-Cl	0.709	2	0.010	0.207	-0.208	**0.552**	-0.017	-0.214	0.164	-0.020	**0.574**	**-0.377**	-0.254	0.173	0.427
Na-EC	0.657	3	**0.535**	0.204	-0.038	-0.052	0.106	-0.094	**-0.467**	**-0.475**	-0.190	-0.076	**-0.404**	0.141	0.568
NO_3-N-DO	0.586	4	0.083	0.275	-0.203	-0.251	-0.108	-0.168	0.284	**0.564**	**-0.327**	-0.059	**-0.515**	0.102	0.670
EC-Ca	0.498														
Station 5026															
EC-Cl	0.837	1	0.018	**0.399**	**0.511**	-0.011	**0.544**	**0.465**	0.137	0.164	0.006	-0.141	-0.040	0.275	0.275
Na-EC	0.745	2	**0.348**	**-0.335**	0.193	-0.091	0.054	0.246	-0.271	-0.065	0.271	**0.313**	**0.639**	0.135	0.410
Na-Cl	0.741	3	**-0.355**	0.154	0.103	**-0.478**	0.077	-0.083	0.003	-0.248	**-0.539**	**0.464**	0.177	0.127	0.537
EC-Ca	0.629	4	0.040	0.246	0.001	**-0.536**	0.031	-0.274	**-0.560**	**0.400**	0.273	-0.067	-0.147	0.106	0.642
Cl-Ca	0.451	5	**-0.386**	0.000	-0.002	0.297	0.051	-0.186	0.223	**0.651**	0.165	**0.430**	0.201	0.094	0.736
Station 5030															
EC-Cl	0.913	1	**-0.311**	**-0.343**	**-0.466**	0.192	**-0.497**	**-0.483**	-0.150	0.066	-0.019	0.138	-0.066	0.330	0.330
Na-EC	0.888	2	-0.286	-0.128	-0.016	**-0.390**	-0.012	-0.015	**0.454**	-0.229	-0.003	**0.330**	**0.618**	0.159	0.489
Na-Cl	0.841	3	0.190	-0.004	-0.202	0.224	-0.112	0.022	**0.458**	-0.021	**-0.668**	**-0.437**	0.107	0.115	0.604
Na-BOD_5	0.536	4	**-0.335**	0.075	0.076	**-0.388**	0.026	-0.032	0.057	**0.821**	-0.144	-0.157	-0.037	0.092	0.696
EC-Ca	0.542														

Station 5024															
EC-Cl	0.736	1	0.044	**0.355**	**0.470**	0.156	**0.538**	**0.427**	**0.338**	0.160	-0.098	-0.067	-0.036	0.268	0.268
EC-Ca	0.581	2	0.277	**0.354**	-0.081	-0.031	0.099	-0.176	-0.196	-0.279	0.175	**-0.507**	**-0.588**	0.169	0.437
Na-Cl	0.660	3	**0.504**	0.168	-0.198	**0.396**	-0.117	-0.199	-0.013	**0.333**	**-0.571**	0.160	-0.076	0.139	0.575
Na-EC	0.644	4	0.278	0.047	0.289	**-0.553**	0.009	0.242	**-0.525**	-0.053	-0.211	**0.372**	-0.105	0.103	0.679
NH_{3-N}-EC	0.460														
Station 5002															
EC-Cl	0.647	1	-0.037	**0.338**	**0.435**	-0.220	**0.492**	**0.418**	0.012	0.220	0.245	-0.174	**-0.300**	0.264	0.264
Na-Cl	0.613	2	**0.399**	-0.181	**0.351**	-0.109	0.095	**0.319**	-0.181	-0.077	**-0.380**	**0.570**	0.231	0.139	0.403
Na-EC	0.593	3	0.064	0.287	0.079	**0.546**	0.160	-0.010	**-0.448**	**-0.542**	0.287	0.024	0.083	0.130	0.533
EC-Ca	0.474	4	**-0.447**	-0.221	0.118	**0.360**	0.220	0.090	0.266	0.290	0.280	0.259	**0.501**	0.110	0.643
NO_{2-N}-DO	-0.375														
Station 5041															
Na-EC	0.877	1	0.183	**-0.388**	**-0.436**	**0.356**	**-0.472**	**-0.444**	0.072	0.182	0.105	-0.147	0.095	0.351	0.351
EC-Cl	0.767	2	-0.214	-0.274	-0.122	-0.090	-0.126	-0.025	**-0.484**	-0.273	**-0.513**	**0.371**	**0.360**	0.202	0.554
EC-Ca	0.750	3	**-0.752**	-0.037	-0.138	0.272	0.075	0.028	-0.237	**0.341**	0.070	0.008	**-0.395**	0.094	0.647
Cl-Ca	0.727														
Na-Cl	0.692														
Station 5043															
SS-pH	0.628	1	-0.132	**0.368**	**0.356**	-0.299	**0.465**	0.224	0.256	**0.399**	-0.001	-0.201	**-0.314**	0.232	0.232
EC-Ca	0.456	2	-0.071	0.223	0.096	**0.326**	0.109	-0.298	**-0.372**	**-0.390**	0.048	**-0.482**	**-0.452**	0.170	0.402
NO_{2-N}-Na	0.401	3	**-0.424**	0.280	**0.396**	0.007	0.077	**-0.356**	**-0.378**	0.074	-0.031	**0.463**	0.298	0.120	0.522
NO_{2-N}-NH_{3-N}	0.384	4	**-0.330**	-0.260	-0.128	**-0.310**	0.022	-0.276	0.107	-0.010	**0.784**	-0.064	-0.068	0.103	0.625
NO_{2-N}-DO	-0.361														
Station 5049															
DO-BOD_5	0.444	1	-0.208	**0.525**	**0.300**	-0.106	**0.464**	-0.091	0.159	-0.120	0.194	**-0.392**	**-0.355**	0.183	0.183
EC-Ca	0.411	2	-0.236	0.070	**-0.472**	-0.181	**-0.409**	**-0.568**	0.041	**-0.321**	0.257	-0.111	-0.103	0.152	0.335
EC-Cl	0.395	3	**0.580**	0.074	-0.279	**0.632**	0.129	-0.244	0.173	0.118	0.097	-0.145	-0.176	0.132	0.468
Na-Cl	0.363	4	-0.187	0.091	-0.237	-0.218	0.124	-0.115	**0.461**	**0.669**	0.035	**0.384**	-0.125	0.113	0.580
pH-NO_{2-N}	0.327	5	0.036	**-0.310**	0.005	-0.133	-0.129	0.037	**0.504**	-0.146	**-0.620**	**-0.325**	**-0.319**	0.104	0.685
Station 5044															
Na-EC	0.724	1	-0.138	**0.430**	0.081	-0.245	**0.549**	**0.436**	-0.175	-0.043	0.226	**-0.387**	-0.071	0.253	0.253
EC-Ca	0.682	2	0.297	0.124	**0.400**	0.287	0.121	0.115	-0.212	**-0.513**	**-0.441**	0.184	**-0.300**	0.168	0.422
NO_{3-N}-NO_{2-N}	0.577	3	-0.060	0.271	0.180	**0.335**	-0.071	-0.273	-0.219	**0.346**	**0.464**	0.170	**-0.536**	0.143	0.565
pH-EC	-0.443	4	0.002	-0.172	**-0.395**	**-0.514**	-0.002	0.021	**-0.583**	-0.017	-0.093	**0.336**	-0.298	0.104	0.669
pH-Na	-0.426														
Station 5047															
Na-Cl	0.492	1	0.159	**-0.398**	**-0.493**	**0.372**	**-0.438**	**-0.339**	-0.128	0.190	-0.044	0.269	0.038	0.192	0.192
EC-Ca	0.490	2	**0.402**	**-0.346**	0.246	-0.287	-0.220	**0.497**	0.120	0.104	**-0.317**	0.256	0.297	0.168	0.359
DO-Cl	-0.390	3	0.284	0.187	-0.209	0.195	0.198	0.031	**0.450**	**0.393**	0.280	-0.271	**0.504**	0.130	0.489
Na-DO	-0.358	4	**0.414**	0.155	0.151	0.173	**0.409**	0.062	**-0.598**	0.288	0.181	**0.318**	-0.080	0.092	0.581
SS-BOD_5	0.300														

Located on the Nif arm of the Gediz River, the station 5026 is subject to the effect of the Kemalpasa industrial district. The first principal component for this station reflects the alkalinity of the water; the second defines the settlement processes of calcium salts in which Ca settles down combining with hydrocarbon, sulphur, carbonate etc.; the third one reflects an organic or industrial purification; the fourth one is a component related with nitrification, and the last PC refer to agricultural activities while the PC loadings of BOD_5 refer to anaerobic contamination or else. It is expected that the principal components of the station 5030 present similar behavior to the station 5026 since they are at the same arm of the river. It seems that the first component reflects the salinity of the water; the second one represents an ammonium based or industrial contamination; the third one designates de-nitrification activities; the last PC reflects a nitrite based organic contamination probably including anaerobic contaminants.

The station 5024 is under the influence of intensive agricultural activities, the principal components can be used to define respectively the alkalinity of the water, the calcium as a nutrient, de-nitrification and an ammonium based purification of agricultural waste water,. The station 5002 has similar behavior to the station 5024. The PCs may be used respectively to represent salinity sourced from irrigation; alkalinity; agricultural fertilizer effect over water quality; a watery period component, on which the quantity of the dissolved oxygen and suspended sediment increase and the concentration of the biologic oxygen demand decrease.

The station 5041 is subject to similar contaminants with 5002. The effect of contaminants sourced from agricultural activities on water quality is less than that of the station 5002, because of the dimension of irrigated region. The PCs may present respectively salinity or alkalinity; the purification of the water from agricultural contaminants; de-nitrification process or an organic based contamination. The station 5043 and 5049 are under the regulatory effects of the Demirkopru Dam. As can be seen from Table 3, almost all principal components of these stations have same amount of contribution to the explained variance. The PCs of 5043 can be defined, respectively as salinity component; a purification component (from the agricultural contaminants); Cl based salinity component (excluding Na salts such as HCl, $CaCl_2$, KCl etc.); a nitrate based contamination (probably caused by agricultural activities). For the station 5049, there is no dominant component. It is not easy to interpret PC's logically, however, the components may be referred to salinity, alkalinity, anaerobic contaminants, nitrogen and de-nitrification, respectively.

The stations 5044 and 5047 are located on the upper part of the basin, away from human activities. All water quality parameters considered are in the first quality class. The statistics in Table 3 verifies this situation. For the station 5044, the first principal component may be used as an indicator of salinity. The second one a sort of a nitrogen based purification component showing existence of organic sedimentation including Cl based contamination; the third one reflects an anaerobic environment. For station 5047, the first principal component represent the suitability of the water against to the salinity; the second one indicate sodium harm namely, alkalinity; the third PC shows a nitrogen based contamination and the last component designate nitrification based on salinity except sodium, calcium and chlorine salts.

3.3 Station Based Analysis

Station Based Analysis (SBA) focuses on a single quality parameter observed in all stations along the basin. It aims to define region behavior of a single contaminant. Therefore, the analysis helps to obtain effective location for observing each quality parameter. The correlation coefficients between the same quality parameters observed for different stations are obtained, and their significance are tested by Student t test. Table 4 gives the statistically significant correlation coefficients and principal components of large variance contribution over water quality. Station based principal component analysis reduced the number of parameters considered, except for BOD_5, DO, $NH_{3\text{-}N}$, $NO_{3\text{-}N}$, and $NO_{2\text{-}N}$. For these parameters, such an exceptional result may be attributed to uniform waste discharges along the watershed. It is not easy to interpret each PC for all parameters. However, the following inferences may be made.

There is no significant decrease in the number of the principal components for BOD_5. Nonetheless, the first component may be used to define the water quality related to agricultural contaminants in the river; the second one may be used as an indicator of an average water quality in the river. The other PCs may be results of specific contamination sources such as industrial wastes. It may be noted there are significant correlations between some quality parameters.

The first two principal components of dissolved oxygen may reflect the risk over aquatic life in the river and nitrification effects on the dissolved oxygen, respectively. Sodium concentration can be explained by only two components. The first component may be the sodium harm of agricultural activities. The second one may represent water purification from sodium. High correlations between the stations are clearly seen for this parameter. Low correlations between the stations are generally seen for Ca. The first principal component of Ca explains large amount of variance. This component may be used to show the river purification from the alkaline; the second one may be used to define an industrial based Ca concentration in the river.

Table 4. Station based principal component analyses

Correlations		Principal Loadings														
Stations	r_{x_i,x_j}	**i**	**5002**	**5005**	**5006**	**5022**	**5024**	**5026**	**5030**	**5038**	**5041**	**5043**	**5044**	**5047**	**5049**	**Var. (%)**	**T. var. (%)**
									BOD_5							
5030-5005	0.789	1	-0.202	-0.219	**-0.449**	**-0.444**	**-0.445**	-0.240	-0.110	**-0.403**	-0.198	0.002	-0.130	0.137	0.089	0.230	0.230
5026-5002	0.762	2	-0.268	**0.529**	-0.076	0.100	0.004	-0.222	**0.524**	0.035	**-0.410**	**-0.300**	-0.195	-0.040	-0.095	0.154	0.384
5038-5024	0.719	3	**-0.516**	-0.234	0.036	0.106	**0.314**	**-0.521**	-0.283	0.282	-0.083	0.150	0.054	0.149	-0.286	0.144	0.529
5024-5006	0.572	4	-0.188	0.206	-0.142	0.018	-0.102	-0.273	0.234	-0.146	**0.455**	**0.430**	0.265	**-0.526**	0.038	0.101	0.629
5024-5022	0.554	5	-0.011	-0.115	0.018	0.167	-0.093	0.047	-0.207	**-0.307**	0.169	**-0.439**	-0.178	**-0.402**	**-0.629**	0.095	0.724

DO

5038-5026	0.681	1	-0.267	-0.275	-0.233	-0.262	-0.293	**-0.342**	-0.103	**-0.361**	**-0.340**	-0.182	**-0.316**	**-0.348**	-0.132	0.366	0.366
5022-5005	0.633	2	0.121	**-0.476**	**-0.311**	**-0.493**	0.285	0.136	-0.266	0.250	0.042	-0.233	**0.337**	0.107	-0.063	0.110	0.476
5044-5038	0.589	3	**0.470**	-0.204	-0.142	-0.292	-0.298	0.066	**0.445**	-0.100	-0.034	**0.348**	-0.028	-0.026	**0.455**	0.100	0.576
5038-5024	0.587	4	0.044	0.166	**-0.494**	-0.042	0.025	-0.038	**-0.314**	-0.041	0.299	**0.639**	-0.174	-0.002	**-0.308**	0.082	0.658
5047-5038	0.543																

Ca

5038-5022	0.662	1	-0.278	**-0.326**	-0.237	**-0.333**	**-0.316**	-0.266	-0.169	**-0.346**	**-0.306**	-0.166	-0.268	**-0.304**	-0.211	0.439	0.439
5022-5005	0.657	2	-0.091	0.019	0.291	0.027	-0.293	0.061	**0.598**	-0.210	0.063	**-0.512**	**0.356**	-0.035	-0.143	0.101	0.540
5038-5024	0.640	3	0.125	0.001	**0.453**	-0.061	-0.220	**-0.391**	-0.234	0.009	0.078	**0.367**	0.266	0.149	**-0.534**	0.092	0.632
5041-5038	0.615																
5024-5022	0.596																

Na

5038-5024	0.820	1	**-0.321**	-0.295	**-0.326**	**-0.340**	**-0.326**	-0.230	-0.217	**-0.354**	**-0.319**	-0.238	-0.213	-0.197	-0.116	0.465	0.465
5038-5022	0.736	2	0.081	**-0.345**	-0.139	-0.180	0.123	-0.151	-0.248	0.089	-0.168	0.216	0.142	0.523	**0.588**	0.126	0.592
5022-5005	0.717																
5041-5006	0.699																
5038-5002	0.699																

Cl

5038-5022	0.750	1	**-0.312**	**-0.327**	-0.295	**-0.356**	**-0.303**	**-0.300**	-0.277	**-0.365**	**-0.318**	-0.138	-0.172	-0.180	-0.091	0.446	0.446
5024-5022	0.700	2	0.078	0.146	0.176	0.129	0.207	0.052	-0.057	0.046	-0.051	0.011	**-0.559**	**-0.480**	**-0.574**	0.161	0.607
5006-5005	0.688	3	0.003	0.150	0.197	0.139	0.060	0.168	**-0.319**	0.063	**-0.302**	**-0.805**	0.116	0.168	-0.039	0.087	0.694
5038-5024	0.686																
5022-5006	0.680																

EC

5038-5022	0.849	1	-0.285	-0.298	-0.236	**-0.336**	**-0.304**	-0.269	-0.267	**-0.334**	**-0.309**	-0.181	-0.264	-0.291	-0.178	0.562	0.562
5038-5024	0.826	2	0.093	0.253	**0.383**	0.071	0.085	-0.109	-0.168	0.096	0.195	**-0.443**	0.066	-0.292	**-0.628**	0.096	0.658
5024-5022	0.795	3	-0.153	-0.083	0.114	-0.179	**-0.318**	**-0.302**	0.294	-0.098	0.209	**-0.445**	**0.534**	0.229	0.238	0.085	0.743
5022-5005	0.782																
5041-5038	0.764																

NH_{3}-N

5044-5002	0.710	1	**-0.367**	-0.065	-0.210	-0.222	-0.221	-0.229	-0.047	-0.128	**-0.443**	**-0.350**	**-0.453**	-0.293	-0.194	0.244	0.244
5041-5026	0.680	2	-0.015	0.077	0.276	-0.101	**-0.392**	**0.512**	**0.339**	0.047	0.296	-0.261	-0.123	0.052	**-0.448**	0.136	0.379
5044-5041	0.710	3	0.084	**0.620**	**0.430**	**0.329**	-0.150	-0.299	0.044	-0.151	-0.113	0.151	0.019	**-0.361**	-0.109	0.114	0.493
5044-5043	0.499	4	**0.502**	-0.179	**-0.301**	-0.135	-0.283	-0.245	-0.164	-0.211	0.143	-0.100	**0.415**	-0.238	**-0.370**	0.100	0.594
5041-5002	0.477	5	-0.219	0.191	0.103	-0.250	-0.009	0.138	**-0.580**	**-0.577**	0.181	0.171	-0.060	0.278	-0.106	0.083	0.676

NO_{2}-N

5043-5006	0.902	1	**0.527**	0.099	**0.535**	0.294	0.132	0.107	0.067	0.037	-0.027	**0.538**	0.036	-0.112	0.036	0.233	0.233
5006-5002	0.855	2	-0.081	**0.534**	-0.134	-0.127	**0.507**	0.263	**0.441**	0.261	0.141	-0.054	0.111	0.119	0.189	0.166	0.399
5043-5002	0.830	3	0.032	0.172	-0.043	-0.025	0.037	0.250	**-0.444**	**0.350**	**-0.486**	-0.097	**-0.433**	-0.223	**0.317**	0.119	0.518
5024-5005	0.657	4	-0.115	**0.321**	0.008	0.000	0.056	0.271	0.095	**-0.469**	-0.126	-0.045	-0.230	**-0.438**	**-0.561**	0.113	0.631
5049-5038	0.446	5	0.162	-0.124	-0.004	**-0.375**	-0.271	0.165	0.103	0.178	**0.568**	-0.008	-0.130	**-0.552**	0.174	0.089	0.720

NO_{3}-N

5041-5002	0.567	1	**0.436**	**0.361**	**0.308**	**0.318**	0.073	0.154	-0.101	**0.418**	**0.373**	-0.133	0.187	0.212	0.182	0.250	0.250
5038-5002	0.549	2	0.042	-0.245	0.124	0.173	**-0.401**	0.105	**-0.626**	0.034	0.104	-0.250	**-0.401**	-0.196	-0.236	0.139	0.389
5038-5005	0.456	3	0.205	-0.087	-0.125	0.230	**0.361**	**-0.426**	0.075	0.128	**0.316**	**0.389**	-0.257	-0.165	**-0.451**	0.104	0.493
5041-5038	0.455	4	0.074	**-0.303**	-0.157	-0.194	0.151	-0.090	-0.132	-0.038	0.114	**-0.393**	**0.375**	**0.524**	**-0.455**	0.082	0.575
5038-5022	0.428																

pH

5038-5022	0.875	1	-0.246	-0.268	-0.255	**-0.320**	-0.284	-0.282	-0.264	**-0.320**	-0.290	**-0.321**	-0.236	-0.246	-0.254	0.611	0.611
5043-5041	0.805	2	**0.339**	**0.431**	0.260	0.027	-0.265	0.189	0.278	-0.178	0.033	-0.174	**-0.564**	-0.217	-0.139	0.069	0.680
5043-5038	0.792	3	**-0.400**	**0.343**	0.272	0.266	-0.043	0.104	-0.116	0.261	-0.247	-0.159	0.280	-0.083	**-0.557**	0.058	0.738
5022-5005	0.777																
5038-5024	0.770																

SS

5005-5002	0.693	1	**0.375**	**0.363**	0.181	**0.372**	**0.385**	0.196	0.241	**0.310**	0.270	**0.314**	0.152	0.072	0.126	0.300	0.300
5024-5005	0.581	2	-0.248	**-0.372**	-0.029	-0.022	-0.166	-0.040	**-0.374**	**0.335**	**0.378**	**0.321**	0.267	**0.389**	0.221	0.134	0.434
5030-5005	0.542	3	-0.032	-0.089	**-0.634**	-0.255	**0.338**	**0.563**	-0.019	-0.006	0.105	0.102	-0.265	0.026	-0.015	0.099	0.533
5024-5002	0.536	4	-0.006	-0.201	**0.329**	0.132	-0.012	0.296	-0.300	0.106	-0.110	0.004	**-0.333**	**-0.489**	**0.532**	0.096	0.629
5024-5022	0.522																

The first principal component of Cl explain large amount of the variance, however there is no significant decrease in the number of the station to be considered in the first PC. Therefore, it can be concluded that each station has almost equal contribution to the first PC. Almost all stations have high correlations for EC. The first principal component of EC has large contribution to the total variance of EC variation along the stations. The number of the stations to be considered in the first PC may be reduced significantly, due to the high correlations between stations. This PC may be used to define the salinity of the river.

As regards nitrogen based contaminants, the first PC of NH_{3-N} may present an agricultural based NH_{3-N} influence in the water; the second is an industrial based NH_{3-N} contamination; and the third one may define the general NH_{3-N} contamination of the river. Since the NO_{2-N} is an unsteady form of the nitrogen, it may not be significant to name physically the principal components. NO_{3-N} shows similar behavior to NH_{3-N}. The first two principal components of NO_{3-N} can be used as an agricultural based NO_{3-N}, and an industrial based NO_{3-N} contamination of river, respectively.

In accordance with the correlation coefficients point of view, the effect of the agricultural activities on pH can be seen throughout the main arm of the river on which agricultural activities are maintained. The first principal component of pH has large contribution to the total variance of pH variation in the river. It can be used to indicate the average acidity of the river. Monitoring pH can be rearranged considering the correlated stations. The first two principal components of the suspended sediment can be used to determine average sediment and agricultural or organic based sedimentation, respectively. The other PCs can be explained by diversity on the source of SS.

4. Conclusion

In the light of the results, the following extractions related with water quality can be made. Kemalpasa industrial district is the main contamination source of the river. It is clearly seen the regulatory effects of the Demirkopru Dam on the contamination; irrigational activities affect salt concentrations, considerably; pH values increase by agricultural activities; the concentrations of nitrogen change by industrial and agricultural activities, Kemalpasa is the main source of the nitrogen based contamination; suspended sediment increase towards downstream of upper basins. The domestic, industrial and agricultural contaminants in the basin are sourced by human activities, expose Izmir Bay to high contaminant loads.

Analyses have shown that Gediz River can be considered as consist of six parts with respect to water quality. These are (1) the outlet of the river including the stations 5006, 5022, 5005, 5038; (2) the Nif Creak including the stations 5026, 5030; (3) the middle part of the river enclosing the station 5024, 5002; (4) the left upper part of the river including the station 5041; (5) the downstream part of Demirkopru Dam including the stations 5049, 5043; (6) the upstream part of Demirkopru Dam including the stations 5044, 5047.

For the outlet part of the river, the contaminants sourced from agricultural, industrial and domestic waste waters have shown their effects in river altogether. Alkalinity is the largest factor over the water quality. Considering parameter based principal components, the quality parameters needs to be monitored for each station can be rearranged, taking principal components explanations above into account.

Nif Creak is exposed to extreme salinity, alkalinity and organic contaminants. This is because of Kemalpasa industrial district as well as agricultural activities in the downstream of the creak. PCs of the stations on the Nif Creak indicate an industrial contamination. On other words, the main quality parameters need to be monitored are industrial based contaminants. Suspended sediment is another parameter needs to be monitored in this part of the river, especially in the downstream of the creak.

The middle part of the river is under the effects of the irrigational wastewater, sourced probably from the drainage water of Marmara Lake irrigation. The Demirkopru Dam changes the concentration of contaminants by its regulatory effect. This effect decrease towards the downstream. In this part of the river, organic based contaminants causing salinity and alkalinity need to be monitored continuously.

For the left upper part of the river, agricultural activities are effective on PCs. Main quality parameters can be considered as salinity or alkalinity. Salinity can be easily represented by electrical conductivity. Monitoring intensity and the number of parameters to be monitored can be decreased considerably.

On the downstream part of the Demirkopru Dam, there are no significant correlations between parameters and no principal component dominant to the others. In this part of the river, water quality is mainly controlled by reservoir discharge. The monitoring intensity may be decreased by suitable reservoir operation rules.

On the upstream part of the Demirkopru Dam, water quality is less influenced by human effects. There are no dominant principal contaminants and parameters on water quality. Alkalinity or salinity is needed to be monitored on this part. Monitoring intensity can be decreased considerably in the station 5047. Suspended sediment can be considered as another important parameter to monitor.

Considering the Station Based Analysis and the usage of the river water, the locations of monitoring can be rearranged for each parameter. Thus, reduction in the number of stations to be monitored or in monitoring intensity can be meaningfully realized considering PCs and correlated stations. Some quality parameters, such as BOD_5, NH_{3-N} require to be monitored in more locations especially in the river sections where correlation coefficients between successive stations are not significant.

As another result of the study, the principal component analysis has been founded as a useful tool to determine type, source and location of contamination in the river. PBA and SBA provides an integrity to evaluate water quality through the river for sustainable usage. The cost of monitoring, manipulation, storage and visualization of the quality observations can be reduced by the PC analyses. The decisions about river quality can be taken readily and accurately. Thus, less but continuous and consistent monitoring is necessary for high quality of water in the Gediz River, regarding the type of contamination.

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