Evaluation of Water Quality for the Kurtbogazi Dam Outlet and the Streams Feeding the Dam in Ankara, Turkey

G. Tozsin, F. Bakir, C. Acar, E. Koç

***Abstract*—**Kurtbogazi Dam has gained special meaning for Ankara, Turkey for the last decade due to the rapid depletion of nearby resources of drinking water. In this study, the results of the analyses of Kurtbogazi Dam outlet water and the rivers flowing into the Kurtbogazi Dam were discussed for the period of last five years between 2008 and 2012. Some physical and chemical properties (pH, temperature, biochemical oxygen demand (BOD_5), nitrate, phosphate and chlorine) of these water resources were evaluated. They were classified according to the Council Directive (75/440/EEC). Moreover, the properties of these surface waters were assessed to determine the quality of water for drinking and irrigation purposes using Piper, US Salinity Laboratory and Wilcox diagrams. The results showed that all the water resources are acceptable level as surface water except for Pazar Stream in terms of ortho-phosphate and BOD_5 concentration for 2008.

***Keywords*—**Kurtbogazi dam, water quality assessment, Ankara water, water supply.

I. Introduction

THE demand for the drinking water in Ankara, the capital city of Turkey, has been increasing recently since the population grows up rapidly in parallel with the developing industrialization. It has reached about 1 million m^3/day in 2013 [1]. Therefore, appreciable importance has been given to the resources of surface water around Ankara to meet this growing demand both in terms of water quality and flow rate. The drinking water demand of Ankara is met by six dams currently, Camlidere, Egrekkaya, Kurtbogazi, Akyar, Cubuk-II, and Bayindir. Kurtbogazi Dam is one of the important water resources for Ankara, which annually supplies 67 million m^3 water for drinking, irrigation and industrial use [2]. It was built in 1967. The dam basin located in Sakarya has an area of 331 km² with the capacity of 101.5 million m^3 water at normal level conditions.

Kurt (Mera) Stream and Pazar Stream having continuous flows that were analyzed in this study are vulnerable to natural and human caused pollution since they are open to atmosphere. They are in danger of being polluted by several contaminants such as sewage system of nearby settlements, solid wastes, natural and artificial fertilizers and pesticides.

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In the scope of this study, the quality of surface water in the Kurt Stream, Pazar Stream, Incegez Tunnel outlet stream feeding Kurtbogazi Dam, one of the biggest dams supplying drinking water to Ankara City, and the dam outlet stream (at the inlet of Ivedik Water Treatment Plant) were evaluated by using the data collected during the period of 2008 and 2012.

II. Characteristics of Study Area

Kurtbogazi Dam takes the name from the lake which it was set on. The lake is located at 40 km north-west of Ankara, near the Ankara-Istanbul Highway, between 40° 17’ and 40° 28’ latitude north, and between 32° 37’ and 32° 46’ east longitude [3], [4] (Fig. 1). There are two main streams feeding the Kurtbogazi Dam. One of them is the Kurt Stream, which is a branch of the Ova Stream and the other is Pazar Stream (Fig. 1).

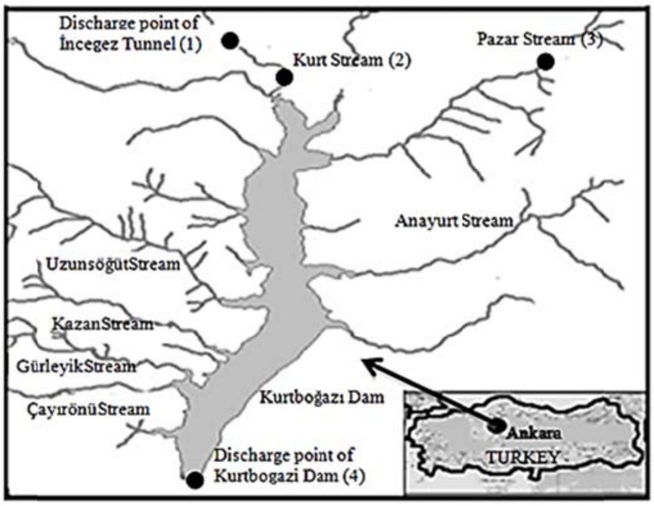

Fig. 1 Location of dam

Terrestrial climate is dominant in the Central Anatolia Region where Kurtbogazi Lake is located. It is hot and dry in summer, and cold and rainy in winter. The rainiest season is spring, and the driest months are between July and September. The monthly average precipitation amounts for 2012 are shown in Fig. 2 [3].

The monthly average flowrate measured by flow monitoring station of DSI (General Directorate of State Water Works) on Kurtbogazi Dam between 1974 and 2012 is shown in Fig. 3. Flow rate is highest in June. Kurtbogazi Dam is one of the most important drinking water sources of Ankara. The water is transferred to Ivedik Water Treatment Plant.

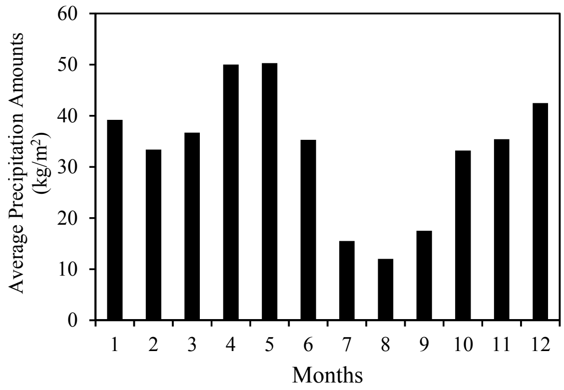

Fig. 2 Total average precipitation amounts in Ankara in 2012 [3]

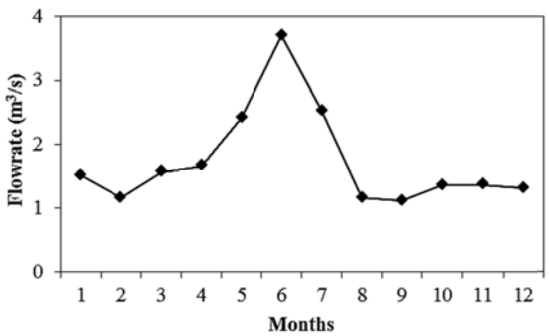

Fig. 3 Monthly average flowrate of Kurtboğazı dam between 1974-2012 [5]

III. Materials and Methods

The sampling points are shown in Fig. 1. The first sampling point is located at the outlet of Incegez Tunnel. The distance of sampling point to Kurtbogazi Dam is about 1000 m. It is under the bridge on the road exiting from Ankara-İstanbul highway to Pazar district. The second sampling point is on Kurt Stream. It is 300 m upstream from Kurtbogazi Dam. The third sampling point is set on Pazar Stream 3000 m upstream from the dam. The waste water flowing through the sewage system of Pazar district had flowed into the Pazar Stream after physical treatment (grizzly and settling basin) till 2009. Then, chemical treatment system was established. The fourth sampling point is set just before the entrance of Ivedik Water Treatment Plant.

The samples were taken for the evaluation of water quality during winter, spring, summer, and autumn between 2008 and 2012. Sampling was conducted considering the stream depth, width, and flow rate. In-situ measurements were conducted for pH (Orion-250A), temperature, and electrical conductivity (WTW-330). BOD_5 and chlorine were analyzed according to Standard Methods [6]. Nitrate and ortho-phosphate were measured by using Ion Chromatography (Dionex ICS-3000).

The parameters of pH, temperature, BOD_5, nitrate, ortho-phosphate, and chlorine in the sampling points were evaluated according to the Council Directive 75/440/EEC concerning the quality required of surface water intended for the abstraction of drinking water in the Member States (1975). In Annex I of this directive, the surface waters were categorized as A1, A2, and A3 in terms of the standard methods of treatment for transforming them into drinking water. According to this classification, simple physical treatment and disinfection is enough for class A1. For the surface waters in class A2, chemical treatment is required in addition to the physical treatment and disinfection. The transforming of A3 class surface water into drinking water requires intensive physical and chemical treatment, extended treatment and disinfection. In Annex II, characteristics of surface water intended for the abstraction of drinking water were tabulated for the aforementioned three categories. According to the Council Directive 75/440/EEC, mandatory and guide values of the parameters for these categories were denoted by I and G, respectively. Moreover, the origin and the specifications of surface waters were determined using Piper's, Wilcox and US Salinity Laboratory (USSL) diagrams in order to assess their appropriateness for drinking and irrigation.

IV. Results and Discussion

The data collected between 2008 and 2012, belonging to four sampling points in the basin, were assessed in terms of pH, temperature, BOD_5, nitrate, ortho-phosphate, and chlorine. According to the Council Directive 75/440/EEC, guide values for pH are between 6.5 and 8.5 for class A1. Fig. 4 presents that all the studied streams correspond to this range although they generally show small variations by years. The pH of Kurt River was high in 2008 but it decreased in the following years. The trends for Incegez Tunnel and Dam Outlet are quite similar.

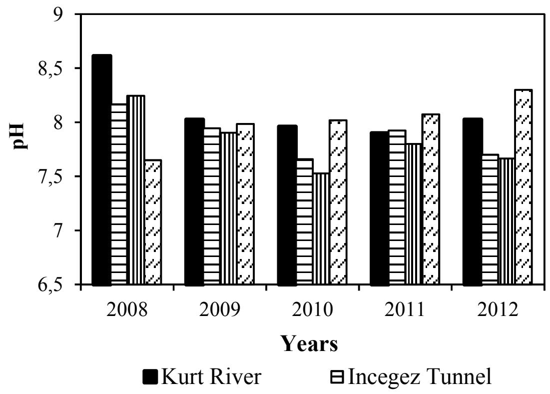

Fig. 4 Variation in pH for different streams between 2008 and 2012

For all the three categories G and I values are 22 and 25, respectively, according to the Council Directive 75/440/EEC. Fig. 5 shows that the temperatures of all the streams are below these values during the period of 2008-2012 so they can be considered to be in the category of A1 in terms of temperature. The water temperature in Incegez Tunnel outlet is a bit colder compared to others since it flows through under the mountain.

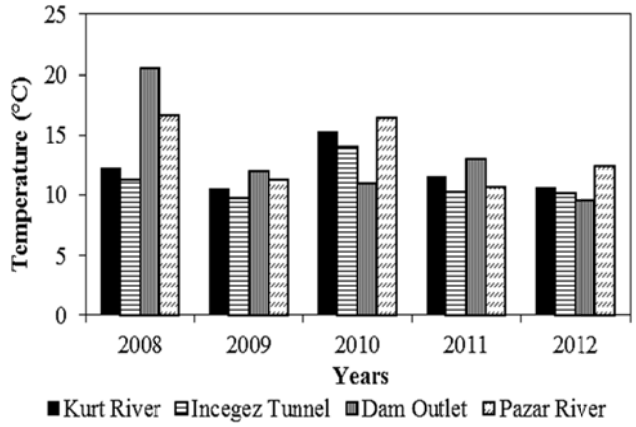

Fig. 5 Variation in temperature for different streams between 2008 and 2012

BOD_5 is a collective parameter that presents the sum of organic compounds that can be decomposed biologically [7]. According to the Council Directive 75/440/EEC, guide values are <3, < 5 and <7 mg/L for the categories of A1, A2, and A3, respectively. The results of BOD_5 show considerable variations by years for all the streams meaning that the effects of external factors show significant change for every year (Fig. 6). The BOD_5 values for Kurt River and Incegez Tunnel outlet generally correspond to the category of A1 except for 2010. The other streams generally have higher BOD_5 values corresponding to A2 and A3 categories. The BOD_5 value is quite high for Pazar River in 2008. The reason is, as mentioned before, the uncontrolled sewage discharge to the river after physical treatment. After the implementation of chemical treatment system, the BOD_5 values decreased to the desired levels.

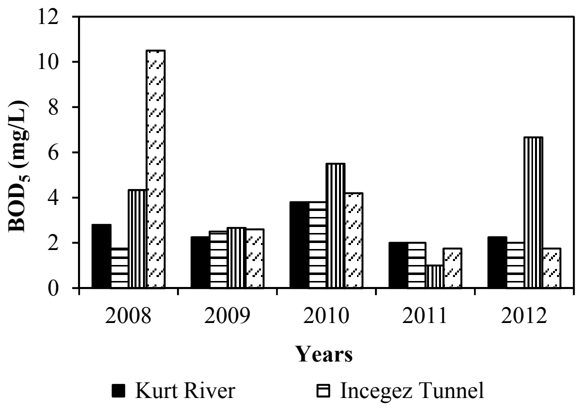

Fig. 6 Variation in BOD_5 concentration for different streams between 2008 and 2012

The presence of excess amount of NO_3 compounds in dead water sources causes eutrophication [8]. It is a kind of an ecosystem response to the addition of artificial or natural substances, such as nitrates and phosphates, through fertilizers or sewage, to an aquatic system [9], [10]. It may cause increase in the population of undesired organisms such as phytoplanktons due to the increased level of nutrients. The depletion of oxygen in water, hypoxia, is one another negative effect of eutrophication [11]. NO_3 is the last oxidation product of organic nitrogen. A contamination should be taken into consideration in the case of a presence of 5-10 mg/L NO_3 in drinking water [12]. According to the Council Directive 75/440/EEC guide and mandatory values for nitrate concentration of A1 class surface water are 25 and 50 mg/L, respectively. Fig. 7 presents that nitrate concentrations in the case streams are much below the guide values. The reason must be the low level of agricultural activities in this district. Although the nitrate concentration in Incegez Tunnel outlet reached 11 mg/L in 2009, it is still in the range of category A1. The water from Egrekkaya Dam, located about 20 km north of Kurtbogazi Dam, flows through this stream to the Kurtbogazi Dam. The reason for the increase in nitrate concentration in Incegez Tunnel outlet must be uncontrolled discharge of domestic wastewater to the Egrekkaya Dam.

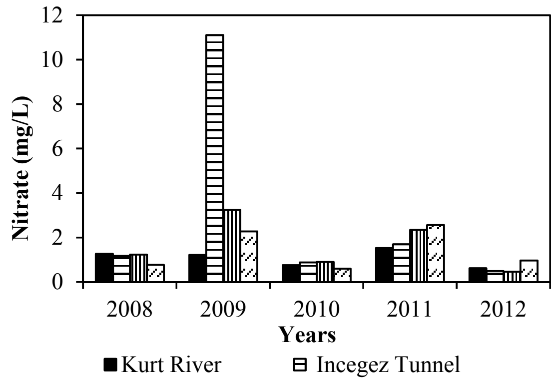

Fig. 7 Variation in nitrate concentration for different streams between 2008 and 2012

Phosphate is a nutritious compound which has vital importance for living organisms. It is a kind of limiting nutrient which controls growing up and primary propagation of algae population [13]. Like nitrate, the increase in phosphate concentration in the water sources due to human activities causes eutrophication, as well [7]. According to the Council Directive 75/440/EEC, guide values for ortho-phosphate concentration are 0.4, 0.7, and 0.7 mg/L for A1, A2, and A3 classes, respectively. Mandatory value is not applicable for this parameter. The four streams can be generally classified as A1 (Fig. 8). However, ortho-phosphate concentration in Pazar River is extremely high for the year of 2008 because of sewage discharge. Dam outlet was also negatively affected by this contamination as it is seen from the data of next year. Then, the contamination was brought under control at following years so all the streams can currently be considered to be A1 class in terms of ortho-phosphate concentration.

For the period of 5 years between 2008 and 2012, chlorine concentration is much less than the allowed limits (200 mg/L for A1 class) in the Council Directive 75/440/EEC so all the streams can be classified as A1 class in terms of this parameter (Fig. 9).

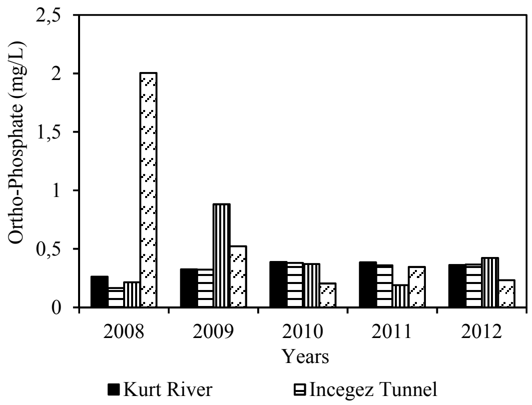

Fig. 8 Variation in ortho-phosphate concentration for different streams between 2008 and 2012

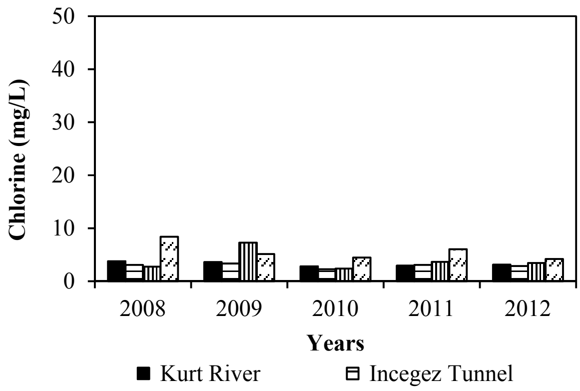

Fig. 9 Variation in chlorine concentration for different streams between 2008 and 2012

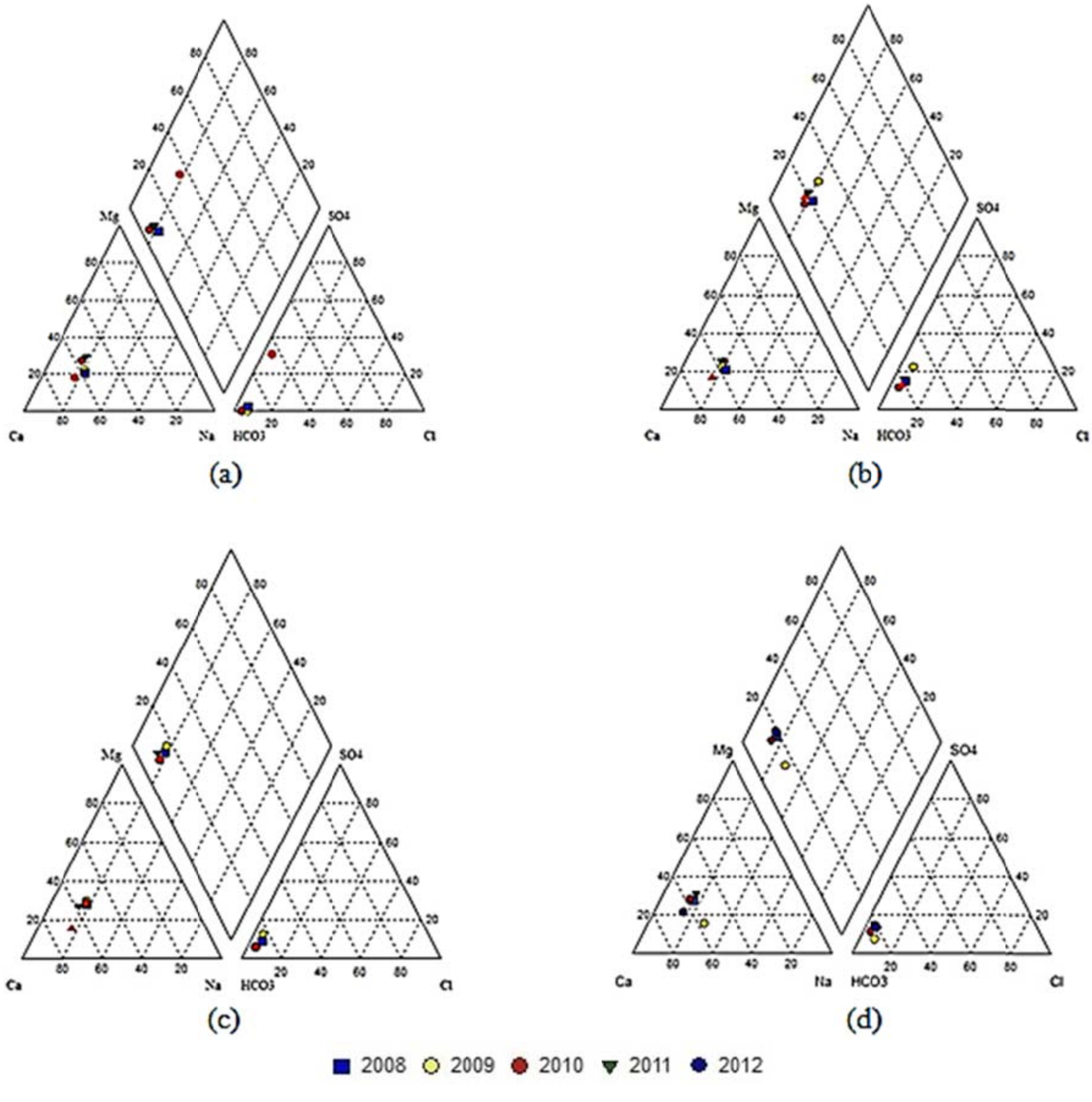

Fig. 10 Piper diagrams of the water samples between 2008 and 2012 (a) Tunnel (b) River (c) Stream (d) Dam

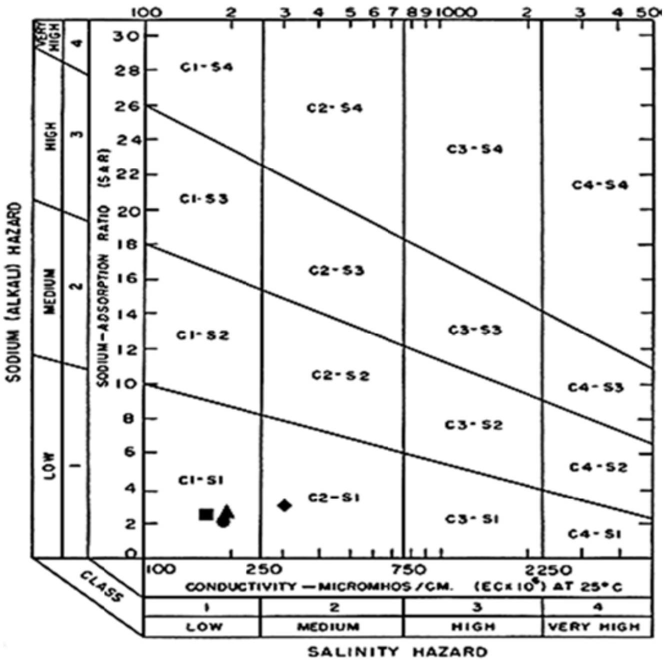

Fig. 11 USSL diagram of water samples for average values of 5 years (2008-2012)

Classifying of water according to US Salinity Laboratory and Wilcox diagrams is carried out by measuring EC (electrical conductivity) and SAR (sodium adsorption rate) values of water; and by measuring EC and Na% values of water, respectively [14]. The values of SAR and EC of studied streams for the average of 5 years (2008-2012) are shown in Fig. 11. According to the results, all the samples taken from the four sampling stations have low salt and sodium contents so these water sources are considered to be in the class of C1-S1 except for Pazar River. The water in Pazar River is classified as C2-S1. The water sources in C1-S1 class are appropriate for any type of soils and plants so they can be used for irrigation. It does not cause trouble in terms of irrigation since washing occurs itself under normal irrigation conditions except for the soils with very low permeability [15].

The EC and Na% values of water samples taken from Kurtbogazi Dam outlet and the streams feeding this dam for the average of last five years are presented by Wilcox diagram in Fig. 12. According to the diagram, all the samples correspond to the field called 'excellent to good'.

The quality of water sources feeding the Kurtbogazi Dam, which are Kurt Stream, Pazar Stream, and Incegez Tunnel outlet, and the dam outlet water were evaluated in terms of pH, temperature, biochemical oxygen demand (BOD5), nitrate, phosphate and chlorine for the years between 2008 and 2012. Moreover, some properties of water sources such as salinity, electrical conductivity and chemical contents were also evaluated using special diagrams. According to Council Directive (75/440/EEC), all the streams can be considered as A1 class in terms of pH, temperature and chlorine concentration for the period of last five years. Kurt Stream and Incegez Tunnel outlet satisfy the requirements for A1 class in terms of all the evaluated parameters. However, the sewage discharge to the Pazar Stream until 2008 negatively affected water quality in terms of ortho-phosphate and BOD_5. This also affected the water quality of dam outlet so the quality of both streams reduced to A2 and even A3 in terms of these parameters. Although an increase in nitrate concentration was observed for Incegez Tunnel outlet in 2009, it is still in acceptable range for class A1.

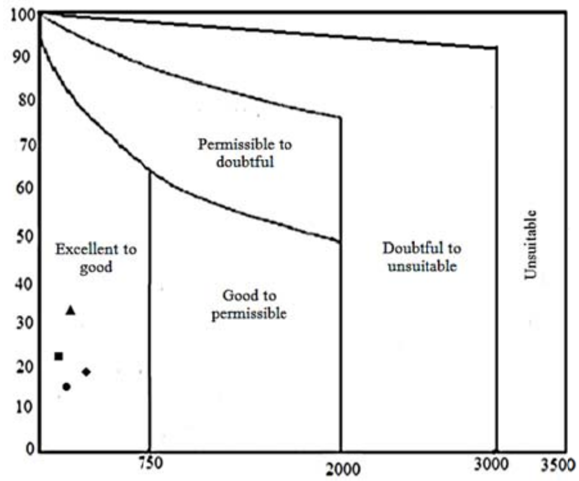

Fig. 12 Wilcox diagram of water samples for average values of 5 years (2008-2012)

V. Conclusion

According to the USSL diagram, it was observed that the streams feeding the dam and the dam outlet stream is in C1-S1 class except for Pazar River. The water sources in the category of C1-S1 are appropriate for irrigation of any kind of soils. According to the electrical conductivity and sodium percentage of the water streams evaluated by Wilcox diagram, all the streams can be classified as 'excellent to good'. The results present that the quality of all the investigated water sources are generally at satisfactory level as surface water. However, for Pazar Steam and Dam outlet, degeneration occurred in the water quality in terms of nitrate and ortho-phosphate concentration in 2008 and 2009 due to the contamination by sewage discharge. After the implementation of chemical treatment system, considerable improvement has been achieved in the quality of these water resources.

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