DRINKING WATER QUALITY MONITORING AND ASSESSMENT FOR THE ATASU DAM LAKE, STREAM GALYAN, TRABZON, TURKEY

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Abstract

Trabzon Province with a total population of 766,782 is the biggest coastal city in the Southeastern Black Sea, Turkey. Since April 2011, domestic water demand of the city has been supplied by the Atasu Dam Lake on the stream Galyan, after being treated at drinking water treatment plants of Trabzon Metropolitan Municipality. The aim of this study covering a six-month period from July to December 2014 is to classify the streams Kışlalı and Galyan feeding the dam lake with reference to the Turkish Water Pollution Control Regulation (TWPCR) and to assess the quality and safety of the untreated reservoir water released from the sluice outlet for drinking purposes based on the permissible levels mandated or proposed by national regulation and standards by monitoring eight water-quality indicators, fluoride (F⁻), ammonium nitrogen (NH₄⁺-N), nitrate nitrogen (NO₃⁻-N), nitrate nitrogen (NO₂⁻-N), total Kjeldahl nitrogen (TKN), total phosphate phosphorus (TP), total organic carbon (TOC), and chemical oxygen demand (COD).

The mean values of a six-month monitoring period revealed that the Atasu Dam Lake has high-quality water with reference to the TWPCR in terms of F⁻ varying between 0.037 and 0.275 mg/L, NH₄⁺-N ranging from 0.004 to 0.011 mg/L, NO₃⁻-N, which were usually under the concentration of 0.002 mg/L, NO₂⁻-N changing between 0.540 and 1.360 mg/L, TKN being between 0.046 and 0.289 mg/L, TOC fluctuating between 1.650 and 4.680 mg/L, and COD having a concentration of 4.310 and 6.880 mg/L. On the other hand, the dam lake has slightly-polluted water with regard to TP, which exceed occasionally the upper threshold of 0.020 mg/L for high-quality water and varied between 0.008 and 0.031 mg/L. Considering the water quality reports from the drinking water treatment plants of Trabzon Metropolitan Municipality for the same period, it can be asserted that quality and safety of the treated reservoir water used for drinking purposes are desirable based on the permissible levels mandated or proposed by national regulations and standards and international directives and guidelines.

Keywords: Atasu Dam, Drinking water quality, Stream Galyan, Trabzon, Treatment plants.

1. Introduction

Safe and good water quality is essential for sustaining basic human functions, health and food production, as well as preserving the integrity of the world’s ecosystems. It provides essential elements, and supports the digestion of food, adsorption, transportation and use of nutrients and the elimination of toxins and wastes from the body. But when polluted it may become the source of undesirable substances dangerous to human health [1, 2]. Reservoirs are critical components of many drinking water supply systems; they can store water when supply exceeds demand, thereby allowing withdrawals during periods when demand exceeds supply. This allows water providers to meet peak demands and maximize supply yields and also provides both drought and flood protection [3]. In...
recent years, drinking water quality monitoring and assessment studies for dam reservoirs and lakes have been carried out in different parts of Turkey [4–16] and in various regions around the world [17–25].

Trabzon Province with a total population of 766,782 is the biggest coastal city in the Southeastern Black Sea [26]. To accomplish this, four main steps are theoretically Domestic water demand of Trabzon people was supplied by the stream Değirmendere aquifer until 1992. However, this area being suitable for tapping groundwater was opened to settlement for various reasons; consequently, groundwater quality in the aquifer was degraded. Although surface water of the stream Değirmendere was used for potable water demand of Trabzon after being treated at drinking water treatment plants of Trabzon municipality, the water supply gradually had been subject to increasing pressure and degradation. Because of the stream Değirmendere water’s deterioration, the stream Galyan began to be utilized as freshwater for the people. But water of the stream Galyan was insufficient especially summer months because of decreasing discharge of the stream and increasing water demand of the city [15].

In order to supply with drinking water demand of Trabzon, the construction of a dam, Atasu, was planned on the stream Galyan. The construction of the dam started in 1998, and the work was completed in 2010 after several interruptions. The dam was situated on main branch of the stream Galyan, located 17 km south–west of Trabzon Province. The reservoir was filled in April 2011, the water from Atasu Dam Reservoir started to be used as the main drinking water source for the Trabzon Province and its towns, namely Akçaabat and Yomra after being treated at the drinking water treatment plants [27, 28].

The aim of this study covering a six-month period from July to December 2014 is to classify the streams Kustul and Galyan feeding the Atasu Dam Lake with reference to the Turkish Water Pollution Control Regulation (TWPCR), and to assess the quality and safety of the untreated water released from the sluice outlet for drinking purposes based on the permissible levels mandated or proposed by national regulation and standards, namely Regulation Concerning Water Intended for Human Consumption (RCWIHC) and Turkish Standard 266–Water intended for human consumption (TS 266), and international directives and guidelines, namely the 98/83/EC numbered Council Directive (EU), World Health Organization (WHO), and United States Environmental Protection Agency (US EPA), by monitoring eight water-quality indicators, namely fluoride (F⁻), ammonium nitrogen (NH₄⁺–N), nitrite nitrogen (NO₂⁻–N), nitrate nitrogen (NO₃⁻–N), total Kjeldahl nitrogen (TKN), total phosphate phosphorus (TP), total organic carbon (TOC), and chemical oxygen demand (COD).

2. The Study Area

With a main branch length of 25.5 km and a catchment area of 191.4 km², the stream Galyan watershed, sub-basin of the stream Değirmendere and near the city of Trabzon, lies between longitudes 39°39’ and 39°45’ and latitudes 40°45’ and 40°52’, and envisions the streams Galyan, main branch, and Kustul, tributary. The watershed accommodates 13 villages where 3391 people inhabit within the watershed according to the 2014 census [23]. Also, the stream Galyan joins the stream Değirmendere, near Esirioğlu town, at the 40°52’54.2” N–39°41’58.2” E geographical coordinates.

The dam reservoir at the normal elevation has a surface area of 0.83 km² and volume of approximately 0.36 hm³. The dam crest is 118 m above thatwag elevation, 372 m in length, and 8 m in width. The catchment area of the dam is 181.5 km². The main purpose of the Atasu Dam Reservoir (Fig. 1) is to provide drinking water with an annual volume of 91.25 hm³ for the people living in Trabzon and another one is to generate hydroelectric energy of 27.14 GWh/yr with an installed capacity of 5 MW [27, 28].

Figure 1. Atasu Dam Lake, Galyan watershed

The sampling stations were dedicatedly selected at the stream Galyan watershed. The first one was Kustul (Fig. 2) on the tributary (40°50’28.2” N–39°42’42.8” E), the second one was Galyan (Fig. 3) on the main branch (40°49’40.7” N–39°41’06.2” E), and last one was Atasu (Fig. 4), located downstream of the Atasu Dam, on the main branch (40°51’51.6” N–39°41’52.5” E).
vigorously, and emptied before refilling for analysis.

At the laboratory, Hydraulic and Water Resources Laboratory, located in Karadeniz Technical University, Trabzon Province, the surface water samples were filtered through a cellulose acetate membrane filter (0.45 μm pore size) under negative pressure. The samples were analysed as soon as possible after they were filtered. 

$F^-$, $NH_4^+$, $NO_3^-$, $NO_2^-$, $TN$, $TP$, $TC$, $TIC$, $TOC$, and COD were measured using a UV-vis spectrophotometer (DR5000) according to standard methods [26]. TKN was calculated as TN-$(NO_3^-+N+NO_2^-+N)$. The analyses were conducted in triplicate for each sample in a temperature–controlled room (21±2°C); the final result was presented as the arithmetic mean of the triplicate analyses.

Classification of water resources intended for drinking water purposes is in accordance with the criteria for classification of Inland Surface Waters Criteria as given by TWPCR [30]. TWPCR divides inland waters into four classes. The water classes according to TWPCR are shown Table 1.

Table 1. Water classes [30]

<table>
<thead>
<tr>
<th>Water Classes</th>
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</thead>
<tbody>
<tr>
<td>Class I</td>
</tr>
<tr>
<td>Class II</td>
</tr>
<tr>
<td>Class III</td>
</tr>
<tr>
<td>Class IV</td>
</tr>
</tbody>
</table>

The quality and safety of the stream and dam reservoir waters used for drinking purposes was assessed based on the national regulation and standards, namely Regulation Concerning Water Intended for Human Consumption [31] and Turkish Standard 266 (TS 266) –Water intended for human consumption [32] and international directives and guidelines, namely the 98/83/EC numbered Council Directive [33], United States Environmental Protection Agency [34], and World Health Organization [35].

In TS 266, the waters intended for human consumption are divided into two classes and two types. Class I refers to spring waters and Class II to water intended for human consumption apart from spring waters. Type I refers to treated spring water while Type II refers to drinking water and water for other uses. Based on the classification by TS 266, the surface waters from Atasu Dam outlet and the streams Galyan and Kuşṭul are regarded as Class II and Type II [32].

3. Material and Methods

Sampling, preservation, and transportation of the surface water samples to the laboratory followed standard methods [29]. Surface water samples of 1L were hand-collected from the 3 sampling stations using high density polyethylene bottles. The bottles were rinsed with the surface waters from the respective stations, shaken...
4. Results and Discussion

The water quality of the streams Kuştul and Galyan feeding Atasu Dam Lake were semimonthly monitored. Temporal variations of monitoring water quality indicators are given at Figures 5–12, respectively.

![Figure 5: Spatial and temporal variations of F⁻ concentration](image)

F⁻ concentrations at the streams Kuştul and Galyan ranged from 0.027 to 0.276 and 0.036 to 0.294 mg/L, the mean values were 0.161 and 0.166 mg/L, respectively. At the Atasu station, the concentrations of F⁻ were measured to be 0.037 and 0.275 mg/L, mean value was 0.151 mg/L.

The water from 3 stations was classified as high quality considering the upper threshold limit of 1 mg/L for F⁻ [30]. However, each station can be also regarded as in the fluoride-poor stream with reference to national [31, 32] and international [33–35] directives and guidelines. According to WHO [35], the minimum concentration of fluoride in drinking-water is approximately 0.5 mg/L with an optimal range of 0.5–1.5 mg/L. In fact, fluoride is not of the essence for human growth and development but is helpful in the prevention of the caries [35].

![Figure 6: Spatial and temporal variations of NH₄⁺–N concentration](image)

At the stream Kuştul, NH₄⁺–N concentration ranged from 0.006 to 0.015 mg/L and mean value was 0.011 mg/L. At the stream Galyan, NH₄⁺–N concentration ranged from 0.005 to 0.046 mg/L and mean value was 0.015 mg/L. At the Atasu station, NH₄⁺–N concentration ranged from 0.004 to 0.011 mg/L, and mean value was 0.006 mg/L.

In regard to the mean NH₄⁺–N concentrations, the water from the stations was classified as high quality [30]. In TS 266 and RCWIHC, the permissible concentration for NH₄⁺ is 0.500 mg/L (0.386 mg NH₄⁺–N/L) complying with the 98/83/EC numbered Council Directive value. Therefore, the NH₄⁺–N concentrations in the study period are compatible with the proposed values.

![Figure 7: Spatial and temporal variations of NO₂⁻–N concentration](image)

NO₂⁻–N concentrations were generally below the upper threshold limit of 0.002 mg/L except for a few studies.

The water from the stations was classified as high quality with regard to NO₂⁻–N concentration except for a few studies. The TS 266 permissible concentration NO₂⁻ is 0.500 mg/L (0.152 mg/L NO₂⁻–N), complying with the RCWIHC and EU guidelines. The US EPA standard and WHO guideline are 1 (0.300 mg NO₂⁻–N/L) and 3 mg/L (0.910 mg NO₂⁻–N/L), respectively. Therefore, the NO₂⁻–N concentrations were within the acceptable levels mandated or proposed by several references.

![Figure 8: Spatial and temporal variations of NO₃⁻–N concentration](image)

At the streams Kuştul and Galyan, the concentrations of NO₃⁻–N ranged from 1.240 to 2.160 and 0.953 to 1.520 mg/L; the mean values were 1.577 and 1.154 mg/L, respectively. Also, at the Atasu station the concentrations of NO₃⁻–N were measured 0.940 and 1.380 mg/L; mean value was 1.094 mg/L.

The fact that the stream Kuştul had more concentration NO₃⁻–N of 37% than the stream Galyan was due to the nitrogen-based fertilizer commonly used for agricultural activities and its vegetation in the Kuştul sub-basin.
In terms of NO₃—N concentrations, the water from each station was classified as high quality [30]. Based on TS 266, the allowable NO₃— concentration is 50 mg/L (11.300 mg NO₃—N/L), complying with the RCWIHC, EU and WHO guidelines. The US EPA drinking water standard for NO₃—N is 10 mg/L. Consequently, the measured concentrations were within the acceptable levels mandated or proposed by several references.

Figure 9. Spatial and temporal variations of TKN

TKN concentrations at the streams Kuştul and Galyan ranged from 0.060 to 0.419 and 0.049 to 0.310 mg/L; mean values were 0.194 and 0.180 mg/L, respectively. The concentrations of TKN were measured as 0.046 and 0.289 mg/L; mean value was 0.182 mg/L at the Atasu station. With reference to upper threshold limit of 0.500 mg/L for TKN, water from each station was classified as high quality [30].

Figure 10. Spatial and temporal variations of total PO₄³⁻—P

The TP concentrations were measured from 0.005 to 0.036 mg/L at the Kuştul, 0.004 to 0.035 mg/L at the Galyan, and 0.008 to 0.031 mg/L at the Atasu. The mean values were calculated as 0.021, 0.021, and 0.019 mg/L, respectively.

The surface waters from each station could not be classify as high quality because of exceeding the upper threshold limit of 0.020 mg/L for the first class in several studies. So, water of each station can be classified as slightly polluted in terms of TP [30].

Figure 11. Spatial and temporal variations of TOC

TOC concentration fluctuated between 2.110 and 5.130 mg/L at the Kuştul, 2.100 and 7.090 mg/L at the Galyan, and 1.650 and 4.680 mg/L at the Atasu. The mean values were calculated as 3.467, 3.946, and 3.422 mg/L, respectively.

Considering the mean values, the water from each station was classified as high quality, with reference to the upper threshold limit of 5 mg/L for TOC [30].

Figure 12. Spatial and temporal variations of COD

The maximum concentrations of COD at the streams Kuştul and Galyan were measured as 8.220 and 9.940 mg/L, respectively. Besides, the maximum concentration of COD was measured 6.660 mg/L at the Atasu station. With reference to upper threshold limit of 25 mg/L for COD, water from each station was classified as high quality.

Trabzon Domestic Water and Sewerage Authority (TISKI) General Directorate has regularly published monthly water quality reports for the drinking water treatment plants. Considering these reports for the same period (Table 2), it is clearly seen that quality and safety of the treated water used for drinking and domestic purposes are suitable [36].
### Table 2. The mean monthly values of the water-quality indicators based on the water quality reports from drinking water treatment plants of Trabzon Metropolitan Municipality [35]

<table>
<thead>
<tr>
<th>Water quality indicators</th>
<th>July</th>
<th>Aug</th>
<th>Sept</th>
<th>Octr</th>
<th>Nov</th>
<th>Dec</th>
</tr>
</thead>
<tbody>
<tr>
<td>pH</td>
<td>7.90</td>
<td>7.90</td>
<td>7.75</td>
<td>7.40</td>
<td>7.35</td>
<td>7.75</td>
</tr>
<tr>
<td>Taste and odor (Ph-Co)</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
</tr>
<tr>
<td>Color</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
<td>A.</td>
</tr>
<tr>
<td>EC (µS/cm)</td>
<td>167</td>
<td>171</td>
<td>176</td>
<td>216</td>
<td>193</td>
<td>195</td>
</tr>
<tr>
<td>Turbidity (NTU)</td>
<td>0.57</td>
<td>0.49</td>
<td>0.73</td>
<td>1.33</td>
<td>1.35</td>
<td>1.30</td>
</tr>
<tr>
<td>TSS (mg/L)</td>
<td>29.00</td>
<td>26.40</td>
<td>27.30</td>
<td>34.25</td>
<td>35.50</td>
<td>33.00</td>
</tr>
<tr>
<td>Ca²⁺ (mg/L)</td>
<td>8.30</td>
<td>8.00</td>
<td>8.70</td>
<td>10.40</td>
<td>9.35</td>
<td>9.80</td>
</tr>
<tr>
<td>WH (*TH)</td>
<td>12.00</td>
<td>7.47</td>
<td>7.45</td>
<td>11.25</td>
<td>13.60</td>
<td>13.00</td>
</tr>
<tr>
<td>Cl⁻ (mg/L)</td>
<td>10.00</td>
<td>8.20</td>
<td>7.45</td>
<td>11.25</td>
<td>13.60</td>
<td>13.00</td>
</tr>
<tr>
<td>NO₃⁻ (mg/L)</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
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<tr>
<td>NO₂⁻ (mg/L)</td>
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</tr>
<tr>
<td>BOD (mg/L)</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
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<tr>
<td>COD (mg/L)</td>
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<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
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<tr>
<td>Alkalinity (mg/L)</td>
<td>86.00</td>
<td>71.00</td>
<td>62.00</td>
<td>70.50</td>
<td>77.00</td>
<td>84.00</td>
</tr>
<tr>
<td>Balance chloride (mg/L)</td>
<td>0.1</td>
<td>0.1</td>
<td>0.2</td>
<td>0.2</td>
<td>0.4</td>
<td>0.2</td>
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<tr>
<td>Organic matter (mg/L)</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
<td>1.0</td>
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<tr>
<td>Detergent (mg/L)</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
<td>N.D.</td>
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<tr>
<td>Total coliform (100 mL)</td>
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<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Fecal coliform (100 mL)</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>Al³⁺ (mg/L)</td>
<td>0.036</td>
<td>0.027</td>
<td>0.070</td>
<td>0.011</td>
<td>0.067</td>
<td>0.035</td>
</tr>
<tr>
<td>Mn²⁺ (mg/L)</td>
<td>0.014</td>
<td>0.003</td>
<td>0.010</td>
<td>0.036</td>
<td>0.027</td>
<td>0.032</td>
</tr>
</tbody>
</table>

A. Acceptable  
N.D. Not detected

### 5. Conclusion and Recommendations

In this study, drinking water resources of Trabzon province with a total population of 766,782, the biggest coastal city in the Southeastern Black Sea, were classified and evaluated, based on the monitoring studies which were semimonthly conducted between July to December 2014.

It was concluded that the water from the streams Kusultan and Galyan and the Atasu Dam Reservoir had high quality according to the TWPCR in terms of the monitored water-quality indicators except for TP in which each stream was classified as slightly polluted.

The fact that the stream Kusultan water had more concentration of 37% in NO₃—N than the stream Galyan water was because of using the nitrogen-based fertilizer and its vegetation in the Kusultan watershed. So, fertilizer usage should be limited in the providing drinking water regions.

Considering the monthly water quality reports covering a six-month period from July to December 2014 for drinking water treatment plants of Trabzon Metropolitan Municipality, it was concluded that quality and safety of the treated waters used for drinking purposes were desirable.

It was also concluded that the treated water should be fluoridated because the water from the Atasu Dam Reservoir is the water source in the fluoride-poor despite the highest F⁻ concentration of 0.275 mg/L.

Despite some limitations related to the monitoring period, such as study duration (6-month), water quality indicators (only eight), and budget constraints associated with data collection, this study is valuable one. Nevertheless, a long term study including more water indicators together with more frequent monitoring and sampling is strongly recommended to better understand the quality and safety of stream Galyan for drinking purposes.
Acknowledgments

This paper is dedicated to memory of a top researcher, a good person, and a beloved friend, Associate Professor Dr. Murat İlhan KOMÜRÇÜ, who was born on May 20, 1972. Murat İlhan KOMÜRÇÜ worked to be Res. Asst., Asst. Prof. Dr., and Assoc. Prof. Dr., respectively, at the Hydraulic Laboratory, Department of Civil Engineering, Faculty of Engineering, Karadeniz Technical University until February 19, 2015 when he was deceased. The authors would like to thank Academic Staff Development Program (ÖYP) Coordination Unit for its financial assistance and Res. Asst. Sinan NACAR accompanying surface water sampling studies.

References


