WATER LEAKAGE ASSESSMENT FROM GEOLOGICAL FORMATIONS AT THE LOCATION OF BADOVC DAM - KOSOVO

S. XH Bublaku
Department of Hydrotechnical Engineering
Faculty of Civil Engineering and Architecture, Prishtina, Kosovo

ABSTRACT

This study aims to assess the opportunity of water leakage from Badovc Lake through geological formations where Badovc dam is built. Badovc dam is built in 1965, representing an embankment Rockfill with inclined core dam placed on impervious foundation, and being 45 m high. Dam is mainly constructed on a serpentinite basement which is plenty of cracks and fissures filled with chalcedon, opal, carbonates and clays. A tectonic zone dipping just vertically is developed beneath the dam. In 2015, two boreholes were drilled in a depth up to 20 m under the dam basement which showed that rocks are cracked and tectonised, and a high level of underground water. Lake hydrological monitoring conducted during the year 2014 and January-June (2015) shows a lack at the water balance of 3,738,905 m³ and 1,885,716 m³ respectively. The appearance of water leaks on the right side of the Badovc dam provides indicators for water leakage through geological formations where the dam is built. The chemical data of several hydrological water components of the Badovc watershed were confronted showing that most of sampled waters are linked with water of the lake.

Keywords: Badovc dam, geological formations, water leakage, water balance

Cite this Article: S. XH Bublaku, Water Leakage Assessment from Geological formations at the location of Badovc Dam – Kosovo, International Journal of Civil Engineering and Technology, 8(11), 2017, pp. 219–227

http://www.iaeme.com/IJCIET/issues.asp?JType=IJCIET&VType=8&IType=11

1. INTRODUCTION

Badovc Dam was built in 1965 and it crosses Gračanka river flow, which is a branch of Sitnica River and belongs to Iber basin. Badovc Lake is originally built for agricultural irrigation and water supply to mines, but after 1990 it was used for drinking water supply of Pristina city. Geological formations of Badovc basin are represented by limestone, clastic formations, magmatic and metamorphic rocks, which are tectonised and fissured to different extent [1]. Dam is constructed mainly on a serpentines basement which is plenty of cracks and fissures filled with chalcedon, opal, carbonates and clays. A tectonic zone dipping just
vertically is developed beneath the dam [2]. The catchment area of Badovc basin is about 104.1 km² and lies to an elevation of 608 to 1200m above sea level. It is characterized by a high vegetation cover where 90% are forests. According to lake water balance, a water amount of 3,738,905 m³ and 1,885,716 m³ for the hydrological year 2014 and the period January – June (2015), respectively, was attributed to water losses from the Lake [3]. This amount of water represents around 17% of the total volume of Lake Water or around 35% of its current water abstraction. Two groundwater emergences along the slopes on the right side of the dam represent the best visible groundwater outflow from the Lake. (Figure 7). The drainage of lake was also confirmed by the chemical data on the water chemistry. In particular, the conservative ion of chloride was applied to show the influence of water Lake in the water sampled from the other hydrologic components of the Badovc Lake watershed [8].

Figure 1 Location of Badovc Lake basin and cross section of Badovc Dam
2. MATERIALS AND METHODS

In 2013 four manual rain gauges in a diameter of 250mm have been installed for a daily monitoring of the rainfall in the basin. A continuous geodesic survey was applied for the monitoring of water level variations in the Lake. A digital Hydrographical Echo Sunder-Hydro Box 2010 device, with measuring frequency every 5 sec, was used for generating bathymetric data which were then interpolated by the Arc-GIS for the construction of the Lake bathymetry. The evaluation of the rivers flow was made across hydrometric regular profiles, where the water speed was measured with Flowatch-JDC instrument. Monthly abstraction of water from the lake was provided by water supplier of Prishtina city. Amount of Evaporation is a measured by a standard evaporation pan located close to lake. Sampling of water from the lake was made by SEBA Liquid Sampler KLL-S, while from rivers, streams, drilling and mines are taken directly in the field. Two boreholes were drilled in a depth up to 20 m under the dam basement which showed that rocks are cracked and tectonised.

3. BADOVC CATCHMENT, LAKE AND DAM CHARACTERISTICS

The Dam and Badovc Lake is located in the north-eastern part of Kosovo, between 21º03’ e 21º23’ E and 42º40’ e 42º36’ N, (Fig 1). Catchment relief is mostly rugged and elevation ranges from 608 to 1200 m above sea level. The Badovc basin comprises 7% gentle slopping, 25% undulating terrain, 42% rugged terrain and 26% steep mountains. It has a total area of 104.1 km². Out of this, 90% are forests, 5% is cultivation land, 1.5% is water and 1.5% construction area. Badovc catchment is characterized by a centripetal river patterns (Mramur, Slivovë and Androvina) that originate from surroundings highlands and drains towards the lake, (Fig.1). The length and width of Badovc Lake are 4.5 km and (250-300) m, respectively. The maximum values of depth, surface and volume that correspond to highest water level 649.75 m (a.s.l), are 45 m, 1.72 km² and 25,590,000 m³, respectively. Badovc dam represents an embankment Rockfill with inclined core dam on impervious foundation. Crest width and length of the Badovc dam are 5.0 m and 260 m respectively. The dam height is 52 m from foundation 601.00m (a.s.l) to top crest 653.00 m (a.s.l) and base width 200 m. Slope upstream and downstream are 1:2 and 1:1.25 [4]. (Figure 1).

4. GEOLOGY AND TECTONICS OF BASIN AND DAM ZONE

4.1. Geology

The watershed of Badovc Lake geologically belongs to Vardar zone which represent the boundary line between the Dinaride zone and Serbian-Macedonian massif [5]. It consists of limestone, clastic formations (ophiolitik melange, sandstone, siltstone, mudstone), magmatic (gabbro-diabase, andesite, peridotite) and metamorphic (quartz-mica schist, chlorite schist, sericite schist, phyllite, gneiss, marble [5],(Fig. 2). The above formations generally have sub-meridional extension, characteristic for dinarides. Metamorphic rocks are of Palaeozoic age, while terrigene formations are of the tertiary age. Ophiolitik melange Jurasis, which belongs to Vardari sub-zone, is partly metamorphosed and presented in the form of a wide belt at the upper part of Slivova stream and continues towards Gjilan (south-east). Badovc basin is characterized from a wide spread of surface formations of Quaternary represented by elluviums, deluvium and prolluviums (sand, silt, clay). Deluviums spread out almost in all over the hilly slopes of basin, whereas prolluviums spread out across the valleys of streams of Mramur, Graçanka and Slivovë, at the medium and bottom parts of the catchment are of Badovc. The dam area is mostly composed of altered and fissured serpentinites [1] with subordinate phyllite schist, clastic formations and gabbro-diabase rocks. Cracks and cleavages in serpentinites are filled with kalcedon, opal, carbonate and clay. Aletration rate and cleavage
of serpentinites are very important to be considered because the dam is supported on these rocks. Presence of a vertical tectonic zone [2] (Figure 3) in the dam profile complicates the situation of water drainage from Lake toward underground waters.

![Figure 2](image2.png)

**Figure 2** Geological map of catchment basin and Badovc Dam 1:100,000 (KPMM-2006)

![Figure 3](image3.png)

**Figure 3** Longitudinal profile along Badovc Lake dam (Regional water supply Prishtina, 1995)

### 5. ASSESSMENT WATER LOSSES FROM WATER BALANCE ANALYZIS

Assessment of losses from Badovs Lake for year (2014) and for the period January- June (2015) is conducted on the basis of water balance of Lake. During the period 2013-2015, several measurements were made at Badovc Basin to determine water balance of the Lake. All of Lake’s water gains and losses and the corresponding changes in the measured lake level over the same period are taken into account in order to calculate the lake water budget, as it appears in the following equation [6]:

\[ \Delta V = (V_P + V_R + V_S + V_{GI}) - (V_{A} + V_{E} + V_{GO} + V_{OF}) \]

Where: \( \Delta V \) = change in lake volume (m³)
\( V_P \) = precipitation on the lake (m³)
\( V_R \) = surface runoff from the catchment (m³)
V_S = stream flow to the lake (m³)
V_GI = groundwater inflow to the lake (m³)
V_A = abstraction from the lake (m³)
V_E = water evaporation from the lake (m³)
V_GO = groundwater outflow from the lake (m³)
V_OF = overflow from the lake (m³)

5.1. Lake Inflow - outflow
Water inflow in the lake for 2014 was 22,577,663 m³ (Fig 4). [3]. (and it comprises (i) river flow to the Lake (V_S), (ii) volume of runoff from the catchment (V_R), (iii) volume of direct precipitation on the lake (V_P) and groundwater inflow (V_GI). For the half of year 2015 respectively, months January-June (2015) water inflow was 22,645,002 m³ (Fig 5). The water outflow from the lake comprises (i) evaporation from the lake surface (V_E), water abstraction (V_A) and infiltration of water from the lake bottom (V_GO). The overflow from the lake (V_OF) represents an additional component of the water outflow from the lake. The total volume of water outflow from the lake over the hydrologic year 2014 was 11,494,758 m³ (Fig 4). [3] while for the half of year 2015 respectively, months January-June (2015) water outflow was 7,164,203 m³ (Fig 5).

5.2. Changes in the water volume of Lake
Water volume changes of Lake are calculated on the basis of fluctuations of water level in the Lake which are a function of the balance between precipitation on the lake, runoff to the lake, evaporation, abstraction and groundwater outflow from the lake [7]. Water volume in Badovc Lake on January 01, 2014 was 9,509,000 m³ while in December 31, 2014 was 16,853,000 m³ that corresponds to water level 637.15 m and 643.60 m (a.s.l) (Fig.4), respectively. In June 30, 2015 water volume was 25,750,000 m³ (Fig 5) that corresponds to water level 649.26 m (a.s.l), The change of water volume in 2014 was 7,344,000 m³ while in January-June (year 2015) was 8,896,895 m³ (Table 1)

Table 1 Lake water level, volume and Change of water volume (January 2014-June 2015)

<table>
<thead>
<tr>
<th>Date/Year</th>
<th>Level (a.s.l)</th>
<th>Lake water volume (m³)</th>
<th>Change of water volume (m³)</th>
</tr>
</thead>
<tbody>
<tr>
<td>01.01.2014</td>
<td>637.15</td>
<td>9,509,000</td>
<td>-</td>
</tr>
<tr>
<td>31.12.2014</td>
<td>643.60</td>
<td>16,853,000</td>
<td>7,344,000</td>
</tr>
<tr>
<td>30.06.2015</td>
<td>649.26</td>
<td>25,750,000</td>
<td>8,896,895</td>
</tr>
</tbody>
</table>

Figure 4 Water balance of Badovc Lake, year 2014
5.3. Water loss from the Lake and Chemical evidences of water loss

The results of Badovc lake water balance in 2014 have shown a difference in water volume of 3,738,905 m³ between inflow and outflow into the Lake. This amount represents about 17% of annual inflow into the Lake for 2014, and is considered as water loss from Lake [6]. The water loss during the period January-June, 2015 was 1,885,716 m³ which is similar with that found for the same time period of year 2014. Such a consistent difference in the water balance of the lake confirms that a considerable groundwater outflow from the lake exists and it’s conditioned by the intensively developed fracture system, which was confirmed by the samples taken from the two boreholes drilled on the foot of the dam (Fig.6). The appearance of water emergences on the right side Badovc dam provides indications for water leakage through geological formations where the dam is built. (Figure 7)
The above groundwater outflow, which represents the water loss from Badovc Lake, was considered to drain mostly into the Hajvalia mine voids [3], [8]. In order to confirm this opinion, the data of chemical analysis from several hydrological water components of the Badovc watershed were confronted (Table 2). In general, solutes that are present in groundwater are derived from two main sources [9]: 1) inputs from atmospheric precipitations and 2) acquisition during weathering and water-rock interaction. According to their behaviour, the chemical signatures are divided in inert and reactive tracers and they may be used effectively to derive physical parameters such as recharge rates and mixing [10]. Among the inert tracers, chloride is the most useful because it is highly mobile and is not involved in the common geochemical reactions that occur in groundwater. In addition, chloride is a conservative element with a mobility in water, very similar to the water molecules [11]. Based on the chloride content in the sampled waters (Table 2, Fig 8), it may be seen the strong influence of the lake water in the waters from leakages on the right side of the dam, piezometer and Hajvalia mine gallery. At the same conclusion could be reached considering the content of sulphates and values of general hardness and electric conductivity of the water (Table 1).

![Figure 8 Map of the Badovc Lake where location of water samples is shown](image)

<table>
<thead>
<tr>
<th>Parameters</th>
<th>Unit</th>
<th>B-4</th>
<th>B-5</th>
<th>B-6</th>
<th>B-7</th>
<th>B-9</th>
<th>B-10</th>
<th>B-19</th>
<th>B-12</th>
<th>B-13</th>
<th>B-16</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>°C</td>
<td>15</td>
<td>13.5</td>
<td>9.5</td>
<td>12.5</td>
<td>15.7</td>
<td>15.5</td>
<td>-</td>
<td>13.7</td>
<td>14.1</td>
<td>22.8</td>
</tr>
<tr>
<td>pH</td>
<td></td>
<td>9.7</td>
<td>9.9</td>
<td>8.2</td>
<td>9.5</td>
<td>5.7</td>
<td>5.5</td>
<td>7.76</td>
<td>8.37</td>
<td>8.1</td>
<td>6.56</td>
</tr>
<tr>
<td>Dissolved oxygen</td>
<td>mg/l</td>
<td>8.66</td>
<td>8.71</td>
<td>-</td>
<td>8.7</td>
<td>7.44</td>
<td>7.41</td>
<td>-</td>
<td>4</td>
<td>7.3</td>
<td>1.1</td>
</tr>
<tr>
<td>Electric conductivity</td>
<td>μS/cm</td>
<td>317</td>
<td>263</td>
<td>271</td>
<td>250</td>
<td>264</td>
<td>262</td>
<td>455</td>
<td>746</td>
<td>1030</td>
<td>1703</td>
</tr>
<tr>
<td>Total dissolved solids</td>
<td>mg/l</td>
<td>159</td>
<td>138</td>
<td>135</td>
<td>126</td>
<td>134</td>
<td>133</td>
<td>227</td>
<td>375</td>
<td>515</td>
<td>852</td>
</tr>
<tr>
<td>General hardness</td>
<td>d°H</td>
<td>12.15</td>
<td>12.01</td>
<td>11.26</td>
<td>11.76</td>
<td>11.56</td>
<td>11.91</td>
<td>15.18</td>
<td>30.03</td>
<td>40.81</td>
<td>58.4</td>
</tr>
<tr>
<td>------------------</td>
<td>-----</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-------</td>
<td>-----</td>
</tr>
<tr>
<td>Ca$^{2+}$ mg/l</td>
<td>58.14</td>
<td>57.53</td>
<td>52.93</td>
<td>56.13</td>
<td>22.05</td>
<td>19.44</td>
<td>24.1</td>
<td>24.46</td>
<td>56.94</td>
<td>281</td>
<td></td>
</tr>
<tr>
<td>Mg$^{2+}$ mg/l</td>
<td>24.31</td>
<td>23.98</td>
<td>23.3</td>
<td>23.62</td>
<td>51.12</td>
<td>55.43</td>
<td>71.3</td>
<td>160.5</td>
<td>198.1</td>
<td>116</td>
<td></td>
</tr>
<tr>
<td>Na$^+$ mg/l</td>
<td>4.101</td>
<td>4.086</td>
<td>4.176</td>
<td>4.083</td>
<td>2.846</td>
<td>2.869</td>
<td>2.797</td>
<td>6.316</td>
<td>4.528</td>
<td>22.1</td>
<td></td>
</tr>
<tr>
<td>K$^+$ mg/l</td>
<td>2.244</td>
<td>2.319</td>
<td>2.484</td>
<td>2.251</td>
<td>0.14</td>
<td>0.227</td>
<td>0.294</td>
<td>4.144</td>
<td>2.994</td>
<td>26.1</td>
<td></td>
</tr>
<tr>
<td>NH$_4^+$ mg/l</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td>0.585</td>
<td>nd</td>
<td>0.111</td>
<td>nd</td>
<td>nd</td>
<td>nd</td>
<td></td>
</tr>
<tr>
<td>NO$_2^-$ mg/l</td>
<td>0.141</td>
<td>0.133</td>
<td>0.109</td>
<td>0.137</td>
<td>0.148</td>
<td>0.19</td>
<td>0.038</td>
<td>0.075</td>
<td>0.126</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>NO$_3^-$ mg/l</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.3</td>
<td>0.2</td>
<td>0.3</td>
<td>0.3</td>
<td>1</td>
<td>0.2</td>
<td>0.7</td>
<td></td>
</tr>
<tr>
<td>HCO$_3^-$ mg/l</td>
<td>245.2</td>
<td>251.3</td>
<td>226.9</td>
<td>228.1</td>
<td>259.9</td>
<td>258.6</td>
<td>361</td>
<td>568.5</td>
<td>789.3</td>
<td>921</td>
<td></td>
</tr>
<tr>
<td>SO$_4^{2-}$ mg/l</td>
<td>35.5</td>
<td>35.4</td>
<td>40.4</td>
<td>43.6</td>
<td>39.1</td>
<td>48.9</td>
<td>36.7</td>
<td>232</td>
<td>269.7</td>
<td>435</td>
<td></td>
</tr>
<tr>
<td>Cl$^-$ mg/l</td>
<td>11.1</td>
<td>11.35</td>
<td>11.46</td>
<td>11.31</td>
<td>10.38</td>
<td>10.4</td>
<td>13.25</td>
<td>6.37</td>
<td>8.09</td>
<td>18.8</td>
<td></td>
</tr>
<tr>
<td>PO$_4^{3-}$ mg/l</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>&lt; 0.01</td>
<td>0.099</td>
<td>&lt; 0.01</td>
<td>0.06</td>
<td>&lt; 0.01</td>
<td></td>
</tr>
<tr>
<td>H$_2$SiO$_3$ mg/l</td>
<td>0.997</td>
<td>nd</td>
<td>nd</td>
<td>0.034</td>
<td>0.777</td>
<td>1.859</td>
<td>0.91</td>
<td>14.03</td>
<td>0.86</td>
<td>4.23</td>
<td></td>
</tr>
</tbody>
</table>

6. CONCLUSIONS
The results of Badovc Lake water balance in (2014) and January-June (2015), confirm a consistent water loss from the lake as result to intensive fracture system developed through the lake basement geological formations. This water loss represents about 17% of the total water inflow into the lake. The water leakage on the right side of the dam represents the best visible exhibition of the groundwater outflow from the lake. The chemical signatures of water further supported the loss of water from the lake.

ACKNOWLEDGMENTS
The author would like to express a special gratitude to technical and administrative staff of Regional Water Company “Prishtina” J.S.C. and surveying staff of the Badovc Lake for providing the authors with data on abstraction rates and the permission to perform different hydro-meteorological measurements. Gratitudes also goes to the staff of the laboratory of Kosovo Hydro-meteorology Institute for chemical analysis

REFERENCES


