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# PHYSICO–CHEMICAL PROPERTIES OF SOME GLACIAL LAKES IN THE ROMANIAN CARPATHIANS

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**Abstract:** Most glacial Romanian Carpathians lakes are located above 1,800 m elevation, in remote or even protected areas, with little anthropic influences, such as local pollution or land use change, and can be considerate open systems with surface in- and outflow. Although the water fluxes are relatively high, glacial mountain lakes represent sensitive areas to human induced disturbances such as atmospheric transported pollutants and pollution generated on site, usually by tourist fluxes. These anthropic inputs can influence water quality and aquatic ecosystems and decrease the ecosystem services provided by the mountain areas. Due to the generally low content of dissolved substances, mountain lakes are sensitive to minor changes in water chemistry, and periodic sampling can serve as early warning in identifying dangerous trends in environmental quality on larger scales. The survey was carried out in 2011 and 2012. In all the surveys, the lakes were sampled in summer–early autumn in the ice-free period. Water samples were collected from three different sites for each lake covering the entire lake surface and were analyzed for a pre-defined set of physical and chemical indicators. Water pH levels ranged between 7.2 – 7.9 and electrical conductivity between 14.2 – 101.5 $\mu S\ cm^{-1}$. Heavy metals show low concentration in the analyzed water lakes: zinc (1.41-4.04 $\mu g\ L^{-1}$), manganese (0.59-5.02 $\mu g\ L^{-1}$), nickel (0.28-1.12 $\mu g\ L^{-1}$), copper (1.45-5.29 $\mu g\ L^{-1}$), cadmium (0.21-0.4 $\mu g\ L^{-1}$) which are below the maximum allowed concentration for first quality class according to Romanian legislation. In contrast, measured lead concentration varied between 1.29-5.54 $\mu g\ L^{-1}$.The results have shown a generally good water quality, the majority of the lakes can be classified as first quality class excepting Bâlea Lake and Pietrosul Lake with values according the second class, due to a slight increase in lead concentration, attributed to atmospheric transport and deposition for Pietrosu Lake, and in Bâlea Lake case due to road traffic or local unknown sources.

**Key words**: mountain lakes, Romanian Carpathians, remote mountain lake, water chemistry, water quality

## 1. INTRODUCTION & STUDY AREA

Mountain areas cover approx one-quarter of the Earth's land surface and constitute home for about 12% of the global population. Besides the general picture, each mountain area has a paramount importance for the communities located in the areas influenced by their presence. According to United Nation Conference on Sustainable Development document (UNCSD, 2012), "…*mountain ecosystems play a crucial role in providing water resources to a large portion of the world's population*." Over the last few decades, our understanding of these remote ecosystems has improved rapidly as a result of several EU-funded projects in Europe (AL:PE 1 and 2, MOLAR and EMERGE). More and more mountain regions are being studied in a similar way around the world, and the results are beginning to show remarkably consistent patterns of contamination in space and time that underline the twin threats of long-distance transported pollutants and global warming. At the same time, they also demonstrate the value of mountain lakes as global sensors of environmental change (Psenner et al., 2002). Recent researches demonstrated that mountain lakes can act as sensitive indicators of environmental change and human impacts such as atmospheric pollution with examples across Europe (Arnaud et al., 2002; Boyle et al., 2004; Curtis et al., 2005; Kopáček et al., 2006; Šporka et al., 2002).

Taking into account the importance of mountain areas in constituting the fresh water resources, at the international level, the need to develop management systems for water/river basins specifically designed for mountain areas was recognized. The EU Water Framework Directive establishes "*….the basic principles of sustainable water policy in the European Union […] in order to coordinate Member States' efforts to improve the protection of Community waters in term of quantity and quality, to promote sustainable water use, to contribute to the control of trans-boundary water problems, to protect aquatic ecosystems and wetlands*"(Mihăiescu & Mihăiescu, 2009).

The Carpathians have been described as Europe's largest mountain range supporting a wealth of natural diversity and a rich cultural heritage (Oszlanyi et al., 2004). They extend over seven countries in an almost semicircular arc (1,500 km long and 50–150 km wide)(Ciucu & Fulga, 2008) but approximately 58% of the chain lies within Romania (Akinyemi et al., 2013). Water quality of Romanian mountain glacial lakes has been addressed in previous studies (Pișotă, 1971) and especially in the last decade, after the perceiving of the importance of mountain lakes as indicators of global and regional changes (Borowiak et al., 2006; Duliu et al., 2008; Romanescu et al., 2010). The Romanian Carpathians are part of the eastern sector of the Alpine mountain system, well identified by the: general direction of the main interfluves, heights, massiveness and structures and preserve a wide diversity of pristine landscapes, most of them protected within national and natural parks. They are divided into three simplified geographical groups: Eastern Carpathians, Southern Carpathians and Occidentals Carpathians.

In the Carpathian Mountains region can be found: glacial and periglacial lakes, karstic lakes, volcanic lakes and antropic lakes. Glacial lakes are best evidenced in alpine zone, carved and shaped by the action of quaternary glaciers. The traces left by these glaciers in the Eastern Carpathians, in Rodna Mountains and especially in the Southern Carpathians, are well kept at heights between 1,700 and 2,400 meters, where year-to-year changes in a lake are common because surface runoff, groundwater inflow, precipitation, temperature and sunlight vary. According to Akinyemi et al., (2013) 150 to 200 glacial lakes are located in Romanian Carpathians. Glacial lakes are of exceptional scientific and aesthetic interest owing to their low content of dissolved solids, and absence of coliform contamination. Recognition of their unique character will help to protect them from abuse.

The sampled lakes were selected in three main areas of the Romanian Carpathians: the Rodna Mountains - 2 sites, Iezerul Pietrosului and Buhăiescu in north-eastern Romania, the Făgăraş Mountains - 2 sites, Bâlea and Călţun and Retezat Mountains - 2 sites, Bucura and Galeşu in the Southern Carpathians (central, southern Romania) (Figure 1).

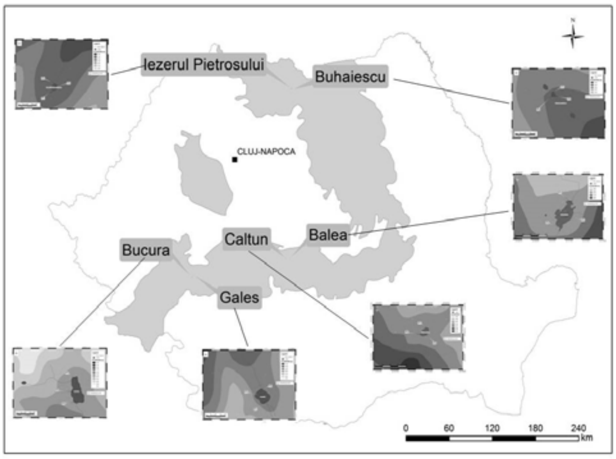


Figure 1, Geographic location of the Carpathian studied Lakes.

Rodnei Mountains (a subdivision of the northern group of the Eastern Carpathian) are the highest (Pietrosul Rodnei peak, 2,303 meters) and most difficult to travel from the Eastern Carpathians and have one of the longest continuous ridges in Romania, with over 50 km from west to east. The northern slopes contain a total of about 23 of alpine glacial lakes.

The Făgăraş Mountains rise to an elevation of 2,544 m. The geology of this region comprises predominantly crystalline rocks, but also includes higher grade metamorphic strata such as gneiss and paragneiss. In Făgăraş Mountains there are 30 glacial lakes.

Retezat Mountains are some of the most beautiful mountains in Carpathians, made famous by the glacier-sculpted landscapes and by the many glacial lakes that are to be found here.

The studied areas were subjected to glaciation during the Quaternary and consequently all the lakes are considered to be glacial in origin being located in catchments oriented predominantly towards the north at elevations from 1,825 to 2,135 m in an alpine to subalpine climate. The lakes catchments are characterized by steep slopes and broad glacial valleys, with massive boulders occurrences, with predominant vegetation constituted by mountain pastures and dwarf pine (*Pinus mugo* subsp. *mugo*). Most of the lakes are located in remote areas accessible by touristic trails only by foot. The lakes are often visited by tourists, camping sites being located in the vicinities in relative controlled conditions. Bâlea Lake is located in a vicinity of a national road, which traverse the southern Carpathians, usually open to traffic only on summer. The ease of access, the presence of accommodation possibilities in buildings located near the lake, generates a massive touristic flux in summer, when cues of hundreds of cars are frequent. The main morphometric characteristics of the studied lakes are presented in table 1.

## 2. METHODOLOGY

The lakes were sampled in 2011 and 2012 in two sampling campaigns each year. In all the surveys, the lakes were sampled in June and September, in the ice-free conditions, and a mean value of the two study years was calculated in order to reduce the interannual variability related to meteorological and hydrological features.

The water samples were collected from the inlet, outlet and center part of the lake at about 50 cm below the water surface. Samples were stored in clean plastic bottles.

Standard laboratory procedures and appropriate conservation criteria (cooler storage boxes, acidification, filtration through a 0.45 μm membrane filter Millipore, to remove particulate material etc.) were followed for analyses of water samples. Water samples were analyzed for a pre-defined set of physical and chemical indicators to permit monitoring of how climate-driven environmental change will affect water quality and their ecosystem functioning and to create a reference database that can be used for comparative assessment and trend delineation.

Water temperature, dissolved oxygen, electrical conductivity (at 25°C) and pH were measured in-situ, using a thermometer and electrodes (WTW instruments), respectively. The concentrations of major anions and cations were measured using ion chromatography (DIONEX ICS-1500 IC system).

The total concentrations of metals were determined using an Inductively Coupled Plasma Mass Spectrometer (SCIEX Perkin-Elmer Elan DRC II). Analyses were made in triplicate and the mean values are reported. The samples with ion concentrations exceeding the calibration range were diluted accordingly and re-analyzed. All reagents were of analytical-reagent grade and all solutions were prepared using ultrapure water with a specific resistance of 18.2 MΩ/cm.

## 3. RESULTS AND DISCUSSION

Mountain lakes water quality is determined by various factors, some governed by the local conditions of the watershed, others by remote influences due to atmospheric transport of various substances generated by natural and anthropic causes. To the local conditions depending of watershed characteristics are added inputs originating on local scale -loads from touristic activity- and on a wider scale -deposition of atmospheric transported pollutants. The low buffering capacity of the mountain water, makes them sensitive to even slight modification of the chemical content.

Data were expressed as mean ± $SE\bar{x}$ (Standard Error of Mean) and were statistically analyzed with the computer program "Statistica 8." The level of statistical significance was established as $P < 0.05$. The obtained data were classified according to Order 161/2006 into five quality classes, and the lake's classification was established by using the percentile system V (90%) (Table 2).

Levels of pH in the studied lakes are summarized in Table 2. All glacial lakes presented pH levels (7.2 – 7.9) that were generally within the acceptable range for lake ecosystems (6.5 – 8.5) and are typical for lakes that are not impacted by acidic depositions. The lower pH values were recorded in the 2011 (Călţun, Bucura, Galeşu lakes) in the early summer period, during the melting of the consistent snow accumulated in winter. The slight decrease of the pH values can be attributed to the concentration of the acidic substances accumulated in the snow layer and washing of the slopes subjected to increase in carbon dioxide caused by bacterial decomposition.

The low electrical conductivity (EC) values (14.2 – 101.5 μS $cm^{-1}$) are characteristic of good quality spring water, the levels are typical of natural levels and remained fairly consistent over time.

The dissolved oxygen (DO) values indicate that the water column is well mixed. The DO values ranged from 8.6 – 12.1 mg O $L^{-1}$. The lower DO concentrations were measured during the summer, when the water temperatures were highest (7.2 mg O $L^{-1}$ at 21°C in July 29, 2011 compared to 9.1 mg O $L^{-1}$ at 15°C in September, 17, 2011 in Buhaiescu lake).

Table 1. Main morphometric characteristics of the studied lakes

| Site / Lake | Altitude, m | Location | Catchment area, $m^2$ | Lake area, ha | Catchment: Lake ratio | Max. depth, m |
|---|---|---|---|---|---|---|
| Rodnei Mountains | | | | | | |
| Iezerul Pietrosul | 1,825 | 47° 35' 54" N<br>24° 38' 52" E | 54.4 | 0.41 | 132.7 | 2.3* |
| Buhăiescu II | 1,890 | 47° 35' 14" N<br>24° 38' 48" E | 62.9 | 0.2 | 314.5 | 5.2* |
| Făgăraş Mountains | | | | | | |
| Bâlea | 2,034 | 45° 36' 13" N<br>24° 37' 07" E | 45.5 | 4.78 | 9.5 | 11.35*<br>16.9** |
| Călţun | 2,135 | 45° 34' 55" N<br>24° 34' 26" E | 18.6 | 0.8 | 23.3 | 11,8* |
| Retezat Mountains | | | | | | |
| Gales | 2,040 | 45° 38' 70" N<br>22°.91' 11" E | 167.206 | 4.04 | 41.4 | 20.1*<br>20.5** |
| Bucura | 2,041 | 45° 36' 24" N<br>22° 87' 65" E | 202.08 | 8.92 | 22.7 | 15.7*<br>17,5** |

*Pişota, I., 1971, **Vespremeanu et al., 2008

Table 2. Mean chemical characteristics of the studied glacial lakes

| Lake | Parameter | Mean ± $SE_{\bar{x}}$ | Confidence - 95% | Confidence 95% | Median | Minimum | Maximum | V (90%) | Quality Class |
|---|---|---|---|---|---|---|---|---|---|
| Iezerul Pietrosului | pH (25°C), pH unit | 7.9 ± 0.08 | 7.7 | 8.1 | 7.9 | 7.7 | 8.2 | 8.1 | OK |
| | EC (25°C), µS $cm^{-1}$ | 28.7 ± 1.11 | 25.8 | 31.5 | 28.7 | 24.8 | 32.5 | 31.5 | - |
| | DO, mg O $L^{-1}$ | 11.4 ± 0.52 | 10.1 | 12.7 | 11.4 | 9.6 | 13.2 | 12.8 | I |
| | $Na^+$, µeq $L^{-1}$ | 21 ± 1.52 | 17 | 24 | 19 | 16 | 28 | 26 | I |
| | $K^+$, µeq $L^{-1}$ | 4 ± 0.40 | 3 | 5 | 5 | 3 | 6 | 5 | - |
| | $Ca^{2+}$, µeq $L^{-1}$ | 227 ± 15.27 | 192 | 262 | 205 | 200 | 341 | 262 | I |
| | $Mg^{2+}$, µeq $L^{-1}$ | 22 ± 2.32 | 17 | 28 | 25 | 14 | 31 | 31 | I |
| | $Cl^-$, µeq $L^{-1}$ | 6 ± 0.17 | 5 | 6 | 6 | 5 | 6 | 6 | I |
| | $NO_3^-$, µeq $L^{-1}$ | 32 ± 3.09 | 25 | 39 | 37 | 17 | 40 | 40 | II |
| | $SO_4^{2-}$, µeq $L^{-1}$ | 141 ± 0.65 | 139 | 142 | 141 | 139 | 145 | 143 | I |
| | Mn, µg $L^{-1}$ | 0.59 ± 0.11 | 0.31 | 0.86 | 0.52 | 0.30 | 0.90 | 0.90 | I |
| | Zn, µg $L^{-1}$ | 4.04 ± 1.01 | 1.46 | 6.63 | 3.26 | 1.33 | 8.40 | 6.80 | I |
| | Ni, µg $L^{-1}$ | 0.84 ± 0.2 | 0.32 | 1.36 | 0.73 | 0.36 | 1.40 | 1.40 | I |
| | Cu, µg $L^{-1}$ | 3.31 ± 0.6 | 1.77 | 4.86 | 3.02 | 1.75 | 6.00 | 4.85 | I |
| | Cd, µg $L^{-1}$ | 0.21 ± 0.05 | 0.08 | 0.34 | 0.22 | 0.00 | 0.38 | 0.33 | I |
| | Pb, µg $L^{-1}$ | 5.54 ± 1.37 | 2.02 | 9.06 | 5.73 | 0.00 | 9.20 | 8.75 | II |
| Buhăiescu | pH (25°C), pH unit | 7.9 ± 0.18 | 7.5 | 8.4 | 7.9 | 7.4 | 8.4 | 8.3 | OK |
| | EC (25°C), µS $cm^{-1}$ | 17.3 ± 0.8 | 15.2 | 19.3 | 16.6 | 15.2 | 20.4 | 19.7 | - |
| | DO, mg O $L^{-1}$ | 8.6 ± 0.28 | 7.8 | 9.3 | 8.8 | 7.2 | 9.1 | 9.0 | I |
| | $Na^+$, µeq $L^{-1}$ | 18 ± 0.92 | 15 | 20 | 18 | 14 | 20 | 20 | I |
| | $K^+$, µeq $L^{-1}$ | 4 ± 0.31 | 3 | 4 | 4 | 3 | 4 | 4 | I |
| | $Ca^{2+}$, µeq $L^{-1}$ | 142 ± 2.34 | 136 | 148 | 142 | 136 | 151 | 148 | I |
| | $Mg^{2+}$, µeq $L^{-1}$ | 15 ± 0.86 | 13 | 17 | 15 | 13 | 18 | 18 | I |
| | $Cl^-$, µeq $L^{-1}$ | 6 ± 0.12 | 5 | 6 | 6 | 5 | 6 | 6 | I |
| | $NO_3^-$, µeq $L^{-1}$ | 37 ± 8.45 | 15 | 58 | 38 | 0 | 61 | 56 | III |
| | $SO_4^{2-}$, µeq $L^{-1}$ | 116 ± 3.56 | 107 | 125 | 117 | 106 | 130 | 125 | I |
| | Mn, µg $L^{-1}$ | 0.69 ± 0.19 | 0.19 | 1.18 | 0.47 | 0.30 | 1.50 | 1.25 | I |
| | Zn, µg $L^{-1}$ | 3.03 ± 1.1 | 0.20 | 5.86 | 2.57 | 0.32 | 7.30 | 5.95 | I |
| | Ni, µg $L^{-1}$ | 0.42 ± 0.02 | 0.36 | 0.47 | 0.41 | 0.36 | 0.50 | 0.48 | I |

Table 2 (continued)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | Cu, µg $L^{-1}$ | 2.66 ± 0.22 | 2.11 | 3.22 | 2.80 | 1.75 | 3.20 | 3.12 | I |
| | Cd, µg $L^{-1}$ | 0.25 ± 0.06 | 0.09 | 0.40 | 0.28 | 0.00 | 0.39 | 0.38 | I |
| | Pb, µg $L^{-1}$ | 3.56 ± 0.74 | 1.64 | 5.47 | 4.29 | 0.00 | 4.90 | 4.73 | I |
| Galeşu | pH (25°C), pH unit | 7.51 ± 0.46 | 6.3 | 8.7 | 7.6 | 6.3 | 8.7 | 8.7 | OK |
| | EC (25°C), µS $cm^{-1}$ | 14.2 ± 0.81 | 12.1 | 16.3 | 14.1 | 12.2 | 16.8 | 16.3 | - |
| | DO, mg O $L^{-1}$ | 12.1 ± 0.31 | 11.3 | 12.9 | 12.0 | 11.1 | 13.2 | 13.0 | I |
| | $Na^{+}$, µeq $L^{-1}$ | 33 ± 2.44 | 27 | 39 | 33 | 26 | 41 | 40 | I |
| | $K^{+}$, µeq $L^{-1}$ | 4 ± 0.13 | 4 | 5 | 4 | 4 | 5 | 5 | I |
| | $Ca^{2+}$, µeq $L^{-1}$ | 74 ± 1.72 | 69 | 78 | 73 | 69 | 80 | 79 | I |
| | $Mg^{2+}$, µeq $L^{-1}$ | 15 ± 1.3 | 12 | 19 | 16 | 9 | 18 | 18 | I |
| | $Cl^{-}$, µeq $L^{-1}$ | 6 ± 0.37 | 5 | 7 | 6 | 6 | 8 | 7 | I |
| | $NO_3^{-}$, µeq $L^{-1}$ | 33 ± 4.19 | 22 | 43 | 32 | 22 | 46 | 44 | II |
| | $SO_4^{2-}$, µeq $L^{-1}$ | 64 ± 0.79 | 62 | 66 | 65 | 61 | 66 | 66 | I |
| | Mn, µg $L^{-1}$ | 0.77 ± 0.22 | 0.20 | 1.33 | 0.73 | 0.00 | 1.50 | 1.35 | I |
| | Zn, µg $L^{-1}$ | 2.54 ± 0.66 | 0.85 | 4.22 | 1.97 | 1.20 | 5.40 | 4.40 | I |
| | Ni, µg $L^{-1}$ | 0.34 ± 0.12 | 0.02 | 0.66 | 0.18 | 0.13 | 0.90 | 0.70 | I |
| | Cu, µg $L^{-1}$ | 1.45 ± 0.41 | 0.41 | 2.49 | 1.56 | 0.31 | 2.50 | 2.40 | I |
| | Cd, µg $L^{-1}$ | 0.4 ± 0.05 | 0.28 | 0.52 | 0.45 | 0.21 | 0.5 | 0.5 | I |
| | Pb, µg $L^{-1}$ | 1.32 ± 0.47 | 0.11 | 2.52 | 1.16 | 0.00 | 2.74 | 2.57 | I |
| Bucura | pH (25°C), pH unit | 7.2 ± 0.21 | 6.7 | 7.8 | 7.4 | 6.3 | 7.7 | 7.7 | OK |
| | EC (25°C), µS $cm^{-1}$ | 14.4 ± 0.23 | 13.8 | 15.0 | 14.5 | 13.7 | 15.2 | 15.0 | - |
| | DO, mg O $L^{-1}$ | 10.3 ± 0.42 | 9.2 | 11.4 | 10.1 | 9.1 | 12.1 | 11.5 | I |
| | $Na^{+}$, µeq $L^{-1}$ | 58 ± 2.98 | 50 | 65 | 58 | 49 | 71 | 65 | I |
| | $K^{+}$, µeq $L^{-1}$ | 4 ± 1.5 | 4 | 5 | 4 | 4 | 5 | 5 | I |
| | $Ca^{2+}$, µeq $L^{-1}$ | 69 ± 2.35 | 63 | 75 | 70 | 60 | 76 | 75 | I |
| | $Mg^{2+}$, µeq $L^{-1}$ | 15 ± 0.86 | 13 | 17 | 15 | 13 | 18 | 18 | I |
| | $Cl^{-}$, µeq $L^{-1}$ | 6 ± 0.44 | 5 | 7 | 6 | 5 | 8 | 7 | I |
| | $NO_3^{-}$, µeq $L^{-1}$ | 12 ± 4.17 | 2 | 23 | 16 | 0 | 23 | 22 | II |
| | $SO_4^{2-}$, µeq $L^{-1}$ | 73 ± 2.89 | 65 | 80 | 73 | 63 | 81 | 81 | I |
| | Mn, µg $L^{-1}$ | 1.46 ± 0.24 | 0.83 | 2.08 | 1.35 | 0.90 | 2.30 | 2.10 | I |
| | Zn, µg $L^{-1}$ | 2.98 ± 0.72 | 1.15 | 4.82 | 2.51 | 1.48 | 6.00 | 4.90 | I |
| | Ni, µg $L^{-1}$ | 1.12 ± 0.38 | 0.15 | 2.10 | 0.96 | 0.14 | 2.70 | 2.10 | I |
| | Cu, µg $L^{-1}$ | 1.91 ± 0.21 | 1.36 | 2.45 | 1.84 | 1.37 | 2.80 | 2.45 | I |
| | Cd, µg $L^{-1}$ | 0.35 ± 0.05 | 0.22 | 0.48 | 0.31 | 0.20 | 0.50 | 0.50 | I |
| | Pb, µg $L^{-1}$ | 2.83 ± 0.58 | 1.35 | 4.32 | 3.15 | 0.90 | 4.20 | 4.15 | I |
| Bâlea | pH (25°C), pH unit | 7.7 ± 0.23 | 7.1 | 8.3 | 7.7 | 7.0 | 8.4 | 8.3 | OK |
| | EC (25°C), µS $cm^{-1}$ | 101.5 ± 2.63 | 94.7 | 108.2 | 102.9 | 91.1 | 107 | 106.9 | - |
| | DO, mg O $L^{-1}$ | 9.9 ± 0.27 | 9.2 | 10.5 | 10 | 8.9 | 10.8 | 10.5 | I |
| | $Na^{+}$, µeq $L^{-1}$ | 18 ± 1.29 | 15 | 21 | 18 | 14 | 23 | 22 | I |
| | $K^{+}$, µeq $L^{-1}$ | 8 ± 0.71 | 6 | 10 | 8 | 6 | 10 | 10 | I |
| | $Ca^{2+}$, µeq $L^{-1}$ | 798 ± 27.50 | 727 | 868 | 791 | 708 | 878 | 154 | I |
| | $Mg^{2+}$, µeq $L^{-1}$ | 148 ± 2.36 | 142 | 154 | 148 | 141 | 156 | 873 | I |
| | $Cl^{-}$, µeq $L^{-1}$ | 62 ± 0.86 | 60 | 64 | 62 | 59 | 65 | 6 | I |
| | $NO_3^{-}$, µeq $L^{-1}$ | 53 ± 14.88 | 14 | 91 | 60 | 0.0 | 88 | 88 | III |
| | $SO_4^{2-}$, µeq $L^{-1}$ | 115 ± 2.03 | 109 | 120 | 116 | 106 | 120 | 119 | I |
| | Mn, µg $L^{-1}$ | 5.02 ± 0.20 | 4.52 | 5.53 | 4.92 | 4.43 | 5.67 | 5.58 | I |
| | Zn, µg $L^{-1}$ | 1.41 ± 0.12 | 1.11 | 1.72 | 1.40 | 1.09 | 1.90 | 1.70 | I |
| | Ni, µg $L^{-1}$ | 0.28 ± 0.09 | 0.04 | 0.52 | 0.32 | 0.01 | 0.52 | 0.51 | I |
| | Cu, µg $L^{-1}$ | 5.29 ± 0.88 | 3.04 | 7.55 | 5.33 | 2.80 | 7.79 | 7.60 | I |
| | Cd, µg $L^{-1}$ | 0.31 ± 0.07 | 0.12 | 0.49 | 0.26 | 0.18 | 0.66 | 0.48 | I |
| | Pb, µg $L^{-1}$ | 4.18 ± 1.13 | 1.28 | 7.08 | 4.13 | 0.0 | 8.70 | 6.51 | II |

Table 2 (continued)

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Căluţun | pH (25°C), pH unit | 7.3 ± 0.18 | 6.8 | 7.7 | 7.4 | 6.4 | 7.7 | 7.6 | OK |
| | EC (25°C), μS $cm^{-1}$ | 27.0 ± 0.42 | 25.9 | 28.1 | 26.8 | 25.8 | 28.4 | 28.2 | - |
| | DO, mg O $L^{-1}$ | 9.8 ± 0.39 | 8.8 | 10.8 | 10.0 | 8.7 | 10.9 | 10.8 | I |
| | $Na^{+}$, μeq $L^{-1}$ | 33 ± 1.7 | 29 | 38 | 35 | 25 | 36 | 36 | I |
| | $K^{+}$, μeq $L^{-1}$ | 4 ± 0.41 | 3 | 5 | 4 | 3 | 6 | 5 | I |
| | $Ca^{2+}$, μeq $L^{-1}$ | 117 ± 2.17 | 112 | 123 | 118 | 111 | 126 | 123 | I |
| | $Mg^{2+}$, μeq $L^{-1}$ | 20 ± 2.05 | 14 | 25 | 18 | 15 | 28 | 26 | I |
| | $Cl^{-}$, μeq $L^{-1}$ | 6 ± 0.18 | 6 | 7 | 6 | 6 | 7 | 7 | I |
| | $NO_3^{-}$, μeq $L^{-1}$ | 4 ± 1.23 | 1 | 7 | 4 | 0 | 8 | 7 | I |
| | $SO_4^{2-}$, μeq $L^{-1}$ | 169 ± 3.63 | 160 | 178 | 167 | 161 | 186 | 178 | I |
| | Mn, μg $L^{-1}$ | 3.14 ± 0.51 | 1.83 | 4.45 | 3.15 | 1.68 | 4.58 | 4.54 | I |
| | Zn, μg $L^{-1}$ | 1.61 ± 0.02 | 1.55 | 1.67 | 1.61 | 1.50 | 1.66 | 1.65 | I |
| | Ni, μg $L^{-1}$ | 0.98 ± 0.1 | 0.73 | 1.24 | 1.05 | 0.50 | 1.14 | 1.14 | I |
| | Cu, μg $L^{-1}$ | 3.01 ± 0.38 | 2.03 | 4.00 | 3.25 | 1.90 | 3.89 | 3.89 | I |
| | Cd, μg $L^{-1}$ | 0.21 ± 0.01 | 0.18 | 0.24 | 0.22 | 0.17 | 0.24 | 0.24 | I |
| | Pb, μg $L^{-1}$ | 1.29 ± 0.31 | 0.51 | 2.08 | 0.86 | 0.85 | 2.67 | 2.16 | I |

Mean values of 2011–2012
SE$\bar{x}$ - Standard Error of Mean
EC- Electrical Conductivity
DO – Dissolved Oxygen
Quality Class according to Order 161/2006
V (90%) - Percentile system

Nitrates concentrations showed variations probably due to the presence of local input from touristic activities and sheep grazing during the summer period. Ionic composition shows relatively low loads characteristic to mountain lakes which have crystalline bedrock a common characteristic of similar lakes located in Europe as asserted by Skjelkvale & Wright **(**1998). Heavy metal concentrations were low despite of potential pollution sources originated from the road traffic. The results can be correlated with the season (temperature of water, raining regime, biological uptake) and with water pH, which may determine the solubilisation of metallic ions. In the spring, the biologic activity can influence directly (by metal uptake) or indirectly (by pH rising) the metal concentrations in water. Chromium, arsenic, and cobalt (not shown in Table 2) were below the detection limits of the method (0.05, 0.2 and 0.1 μg L−1, respectively). Other metals which can be attributed mainly of anthropogenic origin show low concentration in the analyzed water lakes: zinc (1.41-4.04 μg $L^{-1}$), manganese (0.59-5.02 μg $L^{-1}$), nickel (0.28-1.12 μg $L^{-1}$), copper (1.45-5.29 μg $L^{-1}$), cadmium (0.21-0.4 μg $L^{-1}$), which are below the maximum allowed concentration for first quality class according to Order 161/2006. In contrast, measured lead concentration varied between 1.29-5.54 μg $L^{-1}$. The majority of the lakes can be classified as first quality class excepting Bâlea Lake and Pietrosul Lake with values according the second class. The slight increase in lead concentration can be attributed to atmospheric transport and deposition and in Bâlea Lake case due to road traffic or local unknown sources.

## 4. CONCLUSIONS

The differences in water chemistry between the studied glacial lakes can be attributed to several factors such as geology, climate and relief (different input from the weathering, different size of the watersheds, different retention times) and sometimes human influence.

Despite the fact that thousands of tourist are present yearly in the mountain lake catchments the water quality is still maintaining in good quality as shown by the obtained results. At present, the studied lakes seem to be well preserved by acidification risk, but further studies are required to identify the ecological impact of other human disturbance and to determine the sources and impacts of heavy metals, on the quality of the water.

The presence of unique and valorous mountain ecosystems, highly valued by general public, should justify even greater protection and conservation efforts, in the conditions of constantly increasing tourist traffic.

Mountain areas represent a field were, perhaps, more than in other places, measures that are needed to be taken in order to preserve and protect ecosystems, as required by EU Directives, need to be constantly adapted to a possible future climate change.

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