SURFACE WATER - GROUNDWATER INTERACTION IN THE SALACA DRAINAGE BASIN USING STABLE ISOTOPE ANALYSIS

Alise Babre, Andis Kalvāns, Konrāds Popovs, Aija Dēliņa, Inga Retiķe, Jānis Bikše
University of Latvia
alise.babre@lu.lv

Abstract
This paper presents first results of monthly water stable isotope monitoring programme covering the most important surface and groundwater types in the Salaca River basin. The aim is to characterise the isotopic values of different water types in the Salaca River basin, and test if their contribution can be identified in the Salaca river runoff. A monthly groundwater and surface water stable isotope monitoring programme was initiated in August 2015 covering the most of the important surface and groundwater types in the study region – groundwater and surface water in the raised bogs, free-surface groundwater including artificially drained agricultural lands, water emerging from the Lake Burtnieks as well as Burtnieks and Arulika confined aquifers. Preliminary results show that stable isotopes are useful tool to identify distinct water components and their evolution. However, it is needed to continue monitoring programme to draw significant conclusions.
Key words: surface-groundwater interaction, stable isotopes, monitoring, Salaca river basin.

Introduction

The ratios of the stable isotopes in the water ($^{18}O/^{16}O$ and $^{2}H/^{1}H$) routinely presented as the delta value ($\delta^{18}O$ and δD) are a natural conservative tracer of the hydrological cycle with the exception when condensation of water vapour or evaporation from open water surface takes place (Mook, 2001). Terrestrial part of the hydrological cycle is dominated by the precipitation water input that is channelled back to the world ocean as surface and groundwater runoff if not returned to the atmosphere by evapotranspiration. Precipitation water has a characteristic isotopic composition controlled by the air temperature, the source of the water vapour and distance for the vapour transport. Around the world the isotopic composition of the precipitation water can be described by the global meteoric water line (Craig, 1961) that is found to be valid in the Baltic region as well. The precipitation water has a strong seasonality with more depleted values during the winter and more enriched values during the summer (IAEA/WMO 2014). During evaporation remaining liquid water is enriched in heavy isotopes and values of the $\delta^{18}O$ and δD are shifted away from the meteoric water line. In contrast, due to unidirectional transport of the water transpiration from plants and evaporation from soil surface, the isotopic composition of the remaining soil water does not change noticeably.

The aim of this research is to characterise the isotopic values of different water types in the Salaca River basin and test if their contribution can be identified in the Salaca river runoff. A monthly monitoring programme is initiated to observe the primary inputs postulated to be precipitation water and discharge from the Lake Burtnieks and compare their isotopic signature to the water sampled from Rivers Salaca and groundwater discharging into it. Here the first results are reported.

Study Area

The study region is the drainage basin of the Salaca River between its source from Lake Burtnieks and bridge near Vīķi in northern Latvia (Figure 1). The discharge of the Salaca River in the study region is dominated by the Lake Burtnieks that given its large surface area (40.06 km^2; Apsīte *et al*., 2012) has a moderating effect on the discharge fluctuations. The total drainage area of the lake is 2215 km^2; while the rest of the drainage area in the study region is 684 km^2. The largest tributaries of the Salaca in the studied section are Ramata and Iġe.

Lake Burtnieks is a shallow lake located in the North-Eastern part of Latvia. It is a flow lake: the water turnover time is 6 to 7 times a year, 2-3 weeks during the spring and 3 months during the summer (Apsīte *et al*., 2012). The lake surface area is 40 km^2. Long term mean water level of the Lake Burtnieks is 40.07 m a.s.l. The agricultural lands in the studied catchment cover 30 to 40%, bogs are 10% and forests are around 50% (Apsīte *et al*., 2012).

Glacial deposits of the Pleistocene glaciations form the upper part of the geological section within the study area. The thickness varies from a few meters up to 40 meters in elevated territories (Brangulis *et al*., 2000). The predominantly plain terrain is dominated by glacial (*gQ3*), glaciolimnic (*lgQ3*), glaciofluvial (*fQ3*), and peat deposits (*bQ4*) and numerous raised bogs are found. Water abstraction wells are usually installed in aquifers formed by the terrigenous Burtnieks and Arukila formations underlying the Quaternary deposits in the study region. The undulating plain is intersected with the valley of the Salaca river cutting Quaternary and Devonian deposits.

Materials and Methods

A monthly groundwater and surface water stable isotope monitoring programme was initiated in August

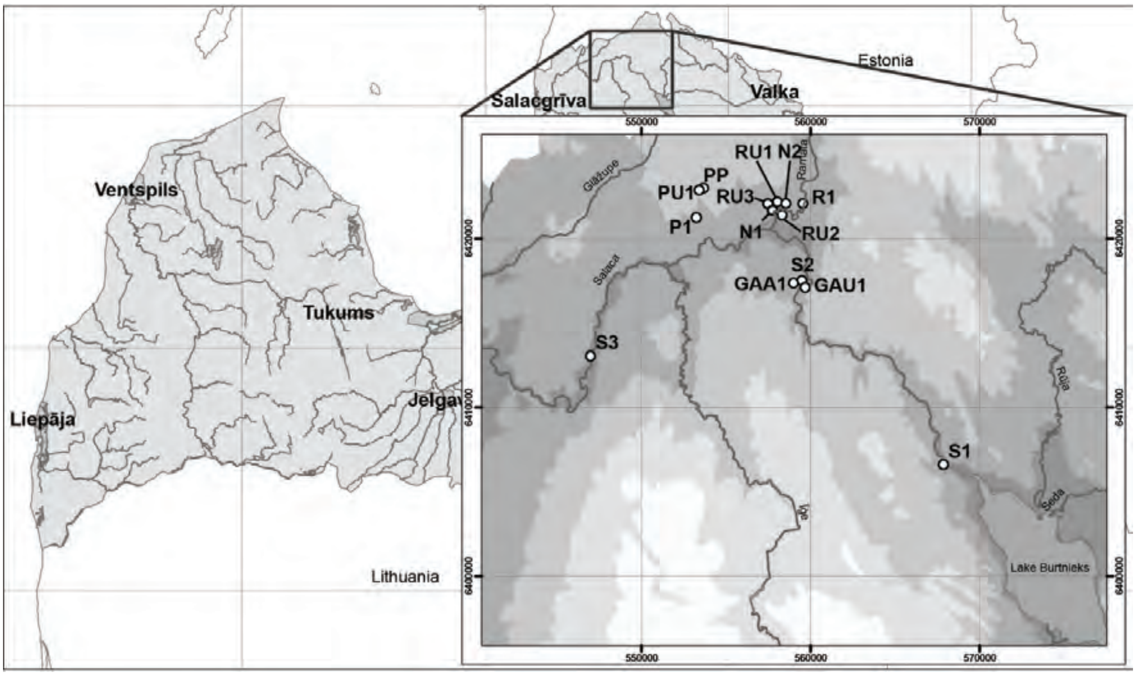

Figure 1. Study area and location of sampling points.

2015. The programme is designed to cover most of the important surface and groundwater types in the study region:

- Groundwater and surface water in the raised bogs: a weighted mean of the precipitation water to some extent modified by the evaporation from open surface (PP, P1 and PU1)
- Free-surface groundwater in sandy soils that might be biased towards the recharge of the depleted autumn-winter precipitation (GAA1)
- Free-surface groundwater in loam (till) soils, including artificially drained agricultural lands that is likely to be closer to the weighted mean of the yearly precipitation in comparison to the groundwater in the sandy soils (RU1, RU2 and RU3)
- water emerging from the Lake Burtnieks that is fed by a mix of groundwater and precipitation water and seasonally modified by the evaporation from free surface (S1)
- Burtnieks and Arukila confined aquifers: an integral value controlled by the local recharge conditions, likely more closely related to groundwater in the sandy-soil (GAU1).

Water samples were collected in 25 ml HDPE double-cap bottles and stored refrigerated until analysis. **δ^{18}**O and **δ^2**H were measured in all samples. Analysis was performed in Environment Dating Laboratory at the University of Latvia on Picarro laser cavity ring down spectrometer. Each sample was measured five times, but to prevent memory effect from previous sample, only average of the last 3 measurements were used to calculate mean value. Standards were placed between every 3 samples as well as at the beginning and at the end of each set of measurements. The repetitiveness of particular data set is ± 0.07‰ for δ^{18}O and ± 0.5‰ for δ^2H respectively; however, it is suggested to use result error ± 0.2‰ for δ^{18}O and ± 1‰ for **δ^2**H (Clark & Fritz, 1997). All samples were measured against internal laboratory standard calibrated against international standard i.e., VSMOW (Vienna standard mean ocean water); accordingly, results can be compared internationally (Aggrwal *et al*., 2007).

Results and Discussion

During the five month observation period, 57 monthly samples were collected from 15 sampling points. Due to unusually low groundwater level in case of shallow wells near Ramata (RU1, RU2 and RU3) or technical problems in case of precipitation traps some sampling points have discontinuous observations. During the first sampling campaign, it was conducted that two sampling points for the river Salaca are insufficient, which explains missing SV3 sample during September 2015.

The slope of precipitation line at Ramata station between **δ^{18}**O and δ^2H is 7.50 that is similar to long term Riga meteoric water line (RMWL) with slope of 7.45 (IAEA/WMO, 2014). Evaporation probably did not affect the results as all precipitation samples fit on the calculated line with determination coefficient 0.99.

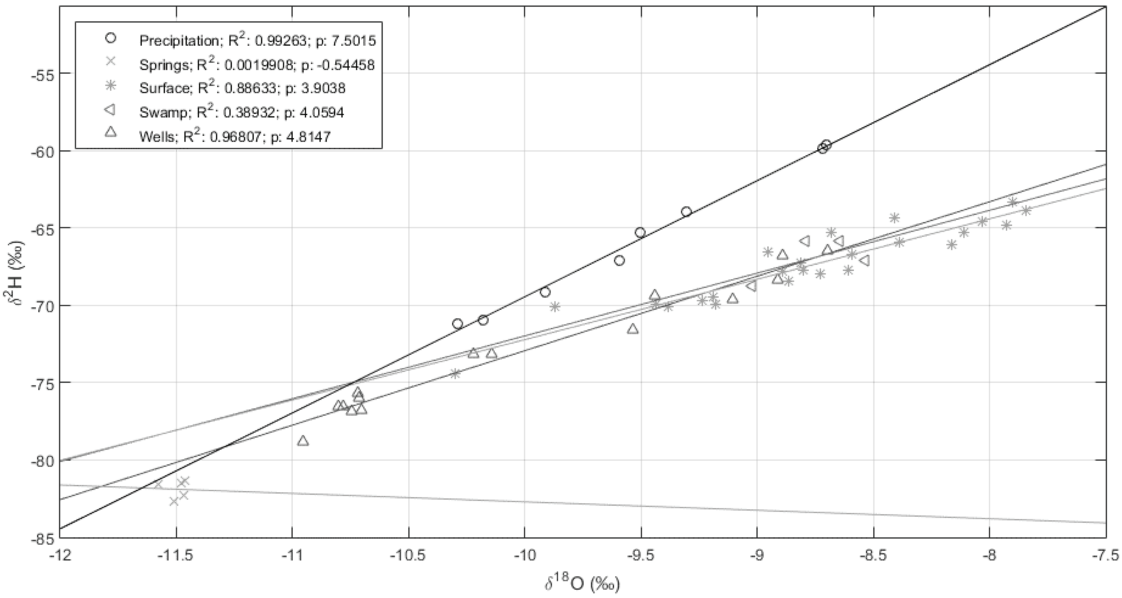

Figure 2. δ[18]O versus δ[2]H values by sampling groups.

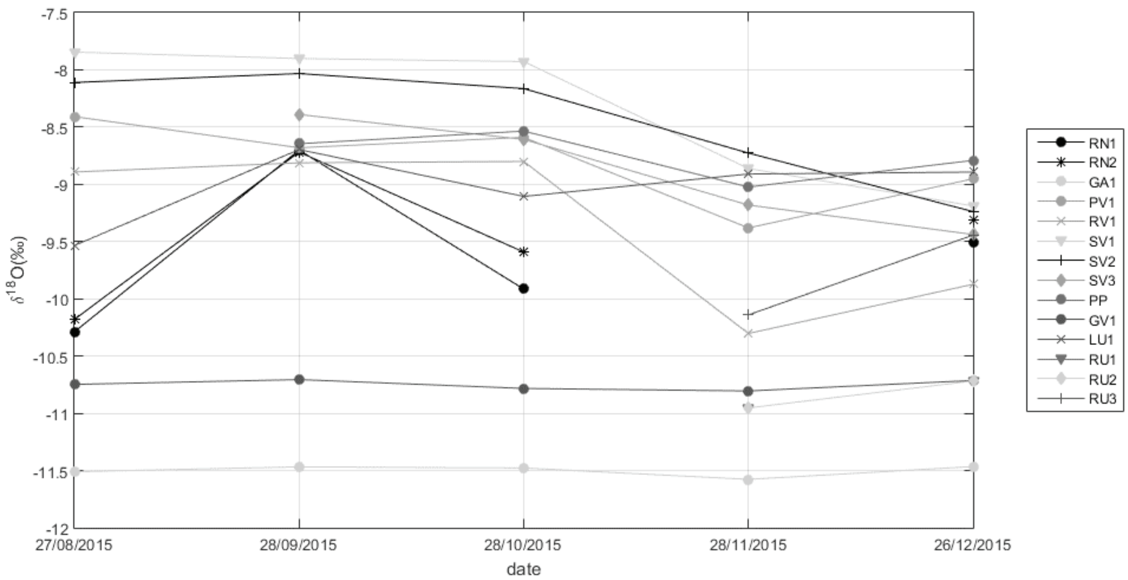

Figure 3. Five month time series of δ[18]O at all sampling locations.

Isotope values of surface samples are spread within a wider range if compared to precipitation (Fig. 2) even though correlation between surface samples is significant i.e., 0.89. Observed values in rivers form essentially different regression slope 3.9. Such shift can be explained by evaporation of river or the source of river. In case of rivers Ramata and Piģele, the impact of raised bog discharge can be the case. In case of the river Salaca, evaporation comes from Lake Burtnieks. It is found that downstream form the Salaca source (SV1 observation point) the evaporation signal is diluted by admixture of more depleted water (Fig. 5).

Govs spring (GAA1) shows constant values in time i.e., range is 0.1 ‰ for δ[18]O and 0.2‰ for δD, even narrower than receptiveness of measurements. Observed temperature and electric conductivity are also constant indicating longterm recharge. Isotope values of Govs spring plot on precipitation line; therefore, we suggest a direct meteoric recharge for Govsala spring.

Wells are within the widest range of isotope values compared to other groups and show more depleted values than surface samples. The most depleted well samples represent samples from the shallow Govsala (GAU1) well in the Burtnieks formation.

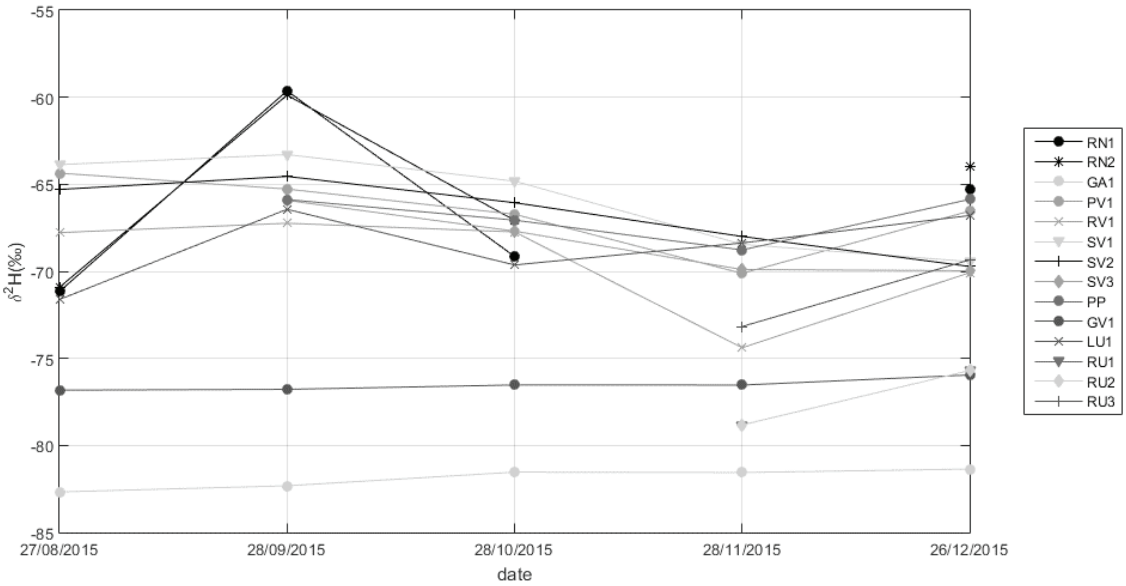

Figure 4. Five month time series of δ^2H at all sampling locations.

The evaporation signal also appears in samples from raised bog (PP, PU1) (Fig. 2) Bog samples change insignificantly during last months (Fig. 3 and Fig. 4) and have somewhat similar character of time series to the river Piģele (PV1). The river Piģele is an outflow from Saklauru raised bog; therefore, similar results were predicted.

Difference between the spring and well at Govsala station (GAA1 and GAU1) is almost 1 ‰ for **δ^{18}**O and 5 ‰ for **δD**, although both the well and the spring show constant values during the observation period. The isotopic signal, as well as different electrical conductivity (518 and 118 µS/cm respectively) clearly points to different groundwater sources. Probably the Govsala spring (GAA1) emerging from Devonian sandstones represent locally recharge unconfined groundwater. The Govsala well (GAU1), on the other hand, more likely represent the regionally recharged confined groundwater.

Every subsequent month the river Salaca depicts more depleted isotope values (Fig. 5). A significant change in values between October and November corresponds to the end of the dry period in November and air temperature drop limiting the evaporation.

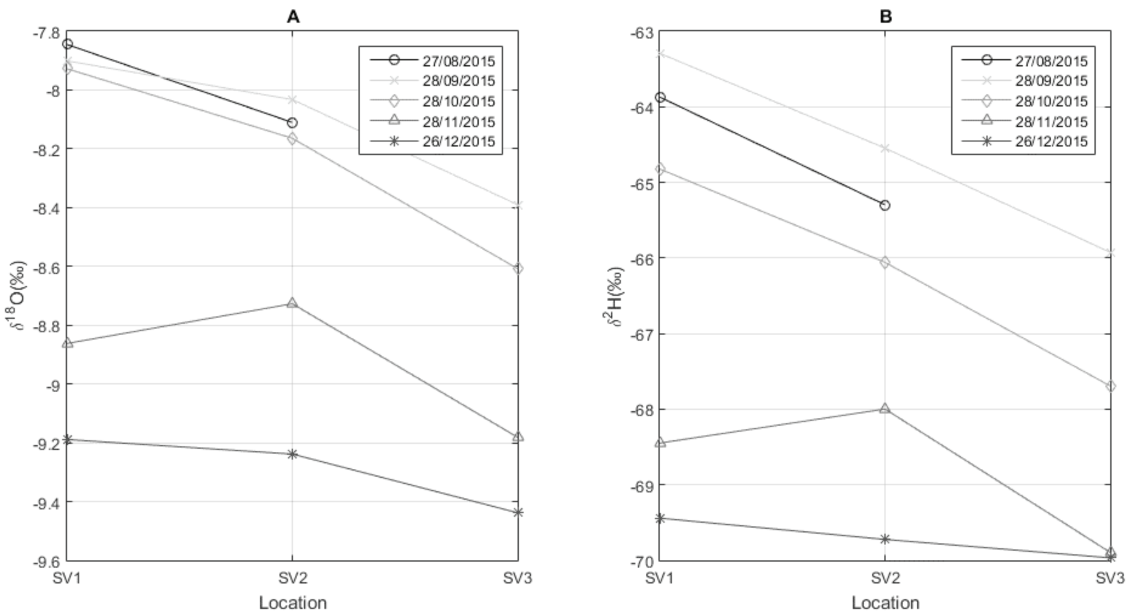

Figure 5. Change of δ^{18}O (A) and δD (B) along the flow path of the river Salaca.

Nevertheless, all months depict depletion of stable isotope values between Salaca observation points along the flow path.

Conclusions

During this study, stable isotopes are found to be a useful tool to identify distinct water components and their evolution, although a longer observation period is needed to draw robust conclusions.

We have found that:

1. Spring Govsala shows stable isotopic values, temperature and electric conductivity during the observation period; therefore, it portrays stable local recharge conditions with water source distinct from that found just a few meters deeper in the Burtnieki aquifer.
2. The water emerging from Lake Burtnieks at the source of the river Salaca in late summer and autumn has a strong evaporation signal, which is gradually diluted downstream.
3. Precipitation trend of Ramata observation station shows an equal slope as observed in Riga weather station 7.41 and 7.45 respectively.

Acknowledgements

This research was supported by NRP project EVIDENnT project 'Groundwater and climate scenarios' subproject 'Groundwater Research'.

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