INVESTIGATION OF SURFACE WATER – GROUNDWATER INTERACTIONS IN THE SALACA HEADWATERS USING WATER STABLE ISOTOPES

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Annotation. This paper presents the first results of a monthly stable isotope monitoring programme covering the most important surface and groundwater types in the Salaca River basin, as well as precipitation.

Preliminary results show that a significant difference exists between isotopic values of different water types; particularly prominent is the evaporation signature of the water emerging from Lake Burtnieks.

Keywords: hydrogeology, stable water isotopes, precipitation, river Salaca.

Introduction

The ratios of the stable isotopes in the water 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). During evaporation remaining liquid water is enriched in heavy isotopes.

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. The isotopic signature of primary inputs postulated to be precipitation water and discharge from the Lake Burtnieks are compared to the water sampled from Salaca River and its tributaries and groundwater discharging into it.

Study area

The study region is the drainage basin of the Salaca River from Lake Burtnieks (source) to bridge near Vīķi in the 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 surface drainage area in the study region is 684 km^2. The largest tributaries of the Salaca in the studied area are Ramata and Iģe.

Glacial deposits of the Pleistocene glaciations form upper part of the geological section within study area. Their thickness varies from few meters up to 40 meters in elevated territories. The predominantly plain terrain is covered by glacial (*gQ3ltv*), glaciolimnic (*lgQ3ltv*), glaciofluvial (*fQ3ltv*) and peat deposits (*bQ4*), as numerous raised bogs are found there. Devonian sandstone aquifers of Burtnieki and Arukila Formations are found below the Quaternary cover. Groundwater from the Burtnieks aquifer is directly discharging to the Salaca River.

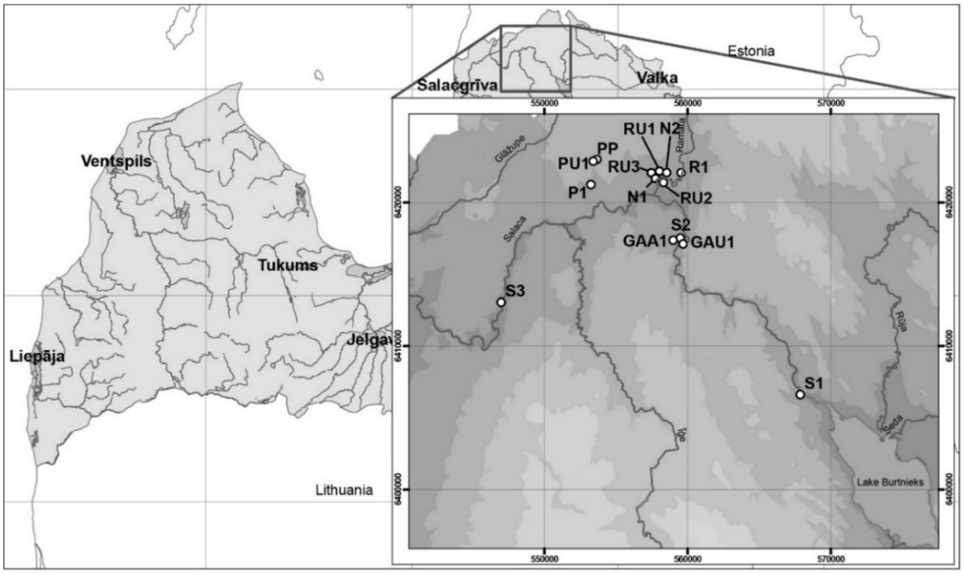

Figure 1. **Study area and location of sampling points**

Materials and methods

A monthly groundwater and surface water stable isotope monitoring programme was initiated on August 2015. The programme is designed to cover most of the important surface and groundwater types in the study region (for locations see Figure 1): (1) groundwater and surface water in the raised bogs (PP, P1 and PU1); (2) free-surface groundwater in sandy soils that might be biased towards the recharge of the depleted autumn-winter precipitation (GAA1); (3) free-surface groundwater in glacial 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); (4) 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); and (5) Burtnieks and Arukila confined aquifers: an integral value controlled by the local recharge conditions, likely more closely related to the *sandy-soil groundwater* (GAU1).

Water samples were collected in 25 ml HDPE double-cap bottles and stored refrigerated until analysis. Delta oxygen-18 and delta deuterium were measured in all samples. Analysis was performed in Environment Dating Laboratory at the University of Latvia on Picarro laser cavity ring down spectrometer. The repetitiveness of particular data set is ±0.07‰ for $\delta^{18}O$ and ±0.5‰ for $\delta^{2}H$ respectively, however it is suggested to use result error ±0.2‰ for $\delta^{18}O$ and ±1‰ for $\delta^{2}H$ (Clark, Fritz, 1997). All samples were measured against internal laboratory standard calibrated against international standard i.e., VSMOW (Vienna standard mean ocean water).

Results

During five months' 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.

The slope of precipitation line at the Ramata station is 7.50 (Figure 2) that is similar to long-term Riga meteoric water line (RMWL) with slope of 7.45 (IAEA/WMO, 2014). Evaporation probably didn't affect the results as all precipitation samples fit on calculated line with correlation factor 0.99.

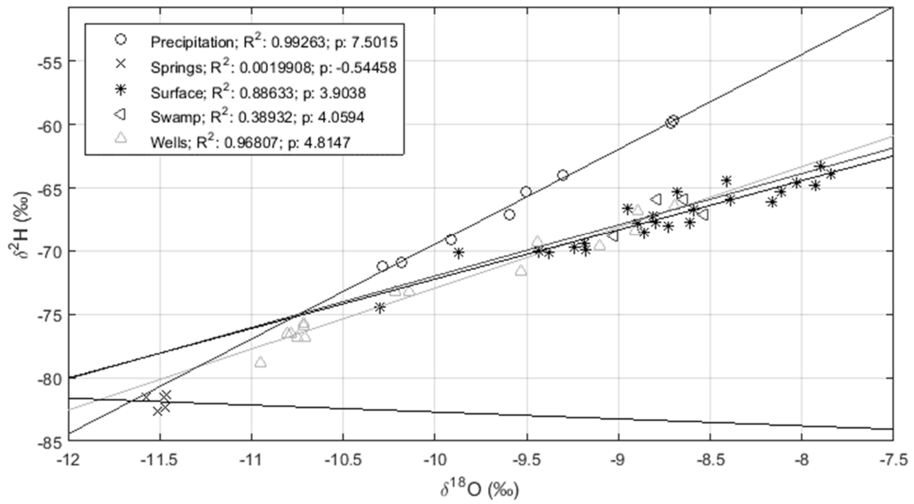

Figure 2. δ^{18}O and **δ^2H values by sampling groups**
In legend: sample groups, R^2 – correlation factor, p – slope of the correlation line

Isotope values of surface water samples are spread within a wider range if compared to precipitation (Figure 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 a shift can be explained by evaporation from the river or from the source of river. In case of rivers Ramata and Pigele impact of raised bog discharge can be the case. In case of the Salaca River the main impact is evaporation at the river source – the Lake Burtnieks. It is found that downstream from the Salaca River source (SV1 observation point) the evaporation signal is diluted by admixture of more depleted water.

The Govsala spring (GAA1) shows constant isotope values in time i.e., range is 0.1‰ for δ^{18}O and 0.2‰ for δ^2H, even narrower than receptiveness of measurements. Observed temperature and electric conductivity are constant as well indicating longer travel time of recharged water. Isotope values of Govsala spring plot on precipitation line, therefore we suggest direct meteoric recharge for Govsala spring.

Wells show similar regression slope as surface water samples with a slight shift toward precipitation values i.e., slope is 4.8. Wells are within the widest range of isotope values compared to other groups and show more depleted values than surface water samples. The most depleted well samples represent groundwater samples from shallow Govsala (GAU1) well in the Burtnieks formation.

The evaporation signal appear in samples from raised bog (PP, PU1) as well as in the samples from small river draining it (PV1). It remains unclear if the evaporation signal from the raised bog can be separated from the evaporation signal of the lake.

Difference between the spring and the well at Govsala station (GAA1 and GAU1) is almost 1‰ for $\delta^{18}O$ and 5‰ for $\delta^{2}H$, although both the well and the spring show constant values during the observation period. The isotopic signal, as well as different electrical conductivity values (518 and 118 µS/cm respectively) clearly points to different groundwater sources. Probably the Govsala spring (GAA1) emerging from Devonian sandstones represent locally recharged unconfined groundwater. The Govsala well (GAU1) on the other hand more likely represent the regionally recharged confined groundwater.

The isotope values of the Salaca River water become more depleted as the autumn progressed. Significant shift in values between October and November corresponds to the end of the dry period in November and air temperature drop limiting the evaporation. Persistent pattern of downstream depletion of stable isotope values are found along the Salaca River.

Acknowledgments

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Summary

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

The water emerging from the Lake Burtnieks at the source of River Salaca at late summer and autumn has a strong evaporation signal, which is gradually diluted downstream.

Precipitation trend of Ramata observation station show equal slope as observed in Riga weather station 7.50 and 7.45 respectively.