The intrusion of saline water into a coastal aquifer containing palaeogroundwater in northern Estonia

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ABSTRACT
Cambrian-Vendian aquifer system (Cm-V) in the northern part of the Baltic Artesian Basin contains fresh Na-Mg-Cl-HCO3 type groundwater originated from glacial meltwater recharge of the Fennoscandian Ice Sheet that covered the area in the Pleistocene (Vaikmäe et al. 2001; Raidla et al. 2009; Raidla et al. 2012). This groundwater is characterized by most depleted isotopic composition recorded in Europe (δ18O values from −18.5%o to −23%, Vaikmäe et al. 2001; Raidla et al. 2009). In the last 60 years, the aquifer system has been extensively used for public water supply. Groundwater exploitation has led to the drawdown of hydraulic heads down to about 15 meters below the pre-development levels (Perens et al. 2012; Erg et al. 2017). Although during the last 25 years the groundwater consumption has decreased and hydraulic heads in most areas have slowly recovered, there are areas where recent increase in population has increased groundwater consumption. The changes in the hydraulic head have led to changes in water quality and to an increase in salinity. The increase in salinity is exemplified by an increase in chloride concentrations from the natural baseline level of ~200 mg/l to 400 mg/l and occasionally up to 750 mg/l. In some areas, the isotopic composition of groundwater has also changed leading to deviations from the Global Meteoric Water Line (GMWL) to which the glacial palaeogroundwater naturally falls. The exact origin of the saline water entering the aquifer system is not clear at present (Figure 1). Up to 90 m thick sequence of overlying Lower-Cambrian claystone (Lontova aquitard) separates the Cm-V aquifer system from shallow aquifers and modern recharge. The rocks forming the aquifer system outcrop under the Baltic Sea which makes seawater intrusion a plausible source of salinity. However, previous studies have shown that the increased salinity in the Cm-V aquifer system could also originate from saline water residing in the weathered upper part of the crystalline basement that directly underlies the aquifer system (Karro et al. 2004; Raidla et al., 2012; Suursoo et al. 2017). In addition, some saline water can be drawn into the shallower parts of the aquifer system from its deeper southern parts. The situation is further complicated by the presence of ancient buried valleys filled with Quaternary sediments that occasionally cut through the Lontova aquitard and Ediacaran sandstone hosting the Cm-V aquifer system (Figure 1). During groundwater consumption fresh modern groundwater in these Quaternary sediments can enter the aquifer system and mix with glacial palaeogroundwater. Here we present groundwater level data together with chemical and isotopic composition of groundwater in the Cm-V aquifer system from three coastal sites in northern Estonia – Kopli peninsula, Viimsi peninsula and Sillamäe area. Our aim is to elucidate whether the increase in salinity observed in these sites is related to seawater intrusion or rather to the intrusion of saline water from the underlying crystalline basement or from the deeper parts of the aquifer system. This can be done by taking into account the differences in chemical and isotopic composition in different saline water end-members (Figure 1). The δ18O values in the Gulf of Finland where the outcrop area of the aquifer bearing rocks is situated range from −7.0%o to −7.7% (Fröhlich et al., 1988). On the other
hand, the saline water in the underlying crystalline basement seems to have a depleted isotopic composition similar to the glacial palaeogroundwater in the aquifer system (Karro et al., 2004; Suursoo et al., 2017). The saline water in the deeper parts of the aquifer system is slightly enriched in $\delta^{18}O$ compared to fresh glacial palaeogroundwater (values $\sim$−15%; Raïdla et al., 2009) Additionally, the mixing of glacial palaeogroundwater with seawater can lead to deviations from the GMWL. Differences in chemical composition in saline water end-members (e.g. Br/Cl and Ca/Cl ratios) also help to trace the origin of salinity in the study area.

**Figure 1.** Conceptual model characterizing the different sources of saline water affecting the glacial palaeogroundwater in the Cambrian-Vendian aquifer system at Viimsi peninsula, northern Estonia. The general features of this conceptual model are characteristic to all other case studies reported in the study.

**REFERENCES**


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