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CC Impacts on Water Resources Availability - A Case Study of the Ljubljana Field and Mura Valley Alluvial Aquifers (Slovenia)

Branka Bračič Železnik[1], Petra Souvent[2], Tina Zajc Benda[3], Barbara Čenčur Curk[3]

[1]Public Water Utility JP Vodovod-Kanalizacija d.o.o., Ljubljana, branka.bracic.zeleznik@vo-ka.si
[2]Slovenian Environment Agency, Ljubljana, petra.souvent@gov.si
[3]University of Ljubljana, Faculty of Natural Sciences and Engineering, Department of Geology, Ljubljana, barbara.cencur@geo.ntf-lj.si

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Introduction

Climate change (CC) impacts on water resources availability could be a critical issue for society and economy. CC effects on water resources are, beside change in recharge processes, closely linked to urbanization and land-use change, population growth as well as other socio-economic trends, what was studied in the frame of South-East European project CC-WaterS.

Slovene test areas were two shallow alluvial aquifers. First, the Ljubljana field aquifer is an unconfined porous aquifer, belongs to Ljubljana basin and is in the central part of the country. It is a source for drinking water for almost 300.000 people. The thickness exceeds 100 m, the groundwater recharges from rainfall (50 %) and from the river Sava (50 %). Mean annual temperature (1971-2000) is 8.99 °C and mean annual precipitation (1971-2000) 1403 mm. The three quarters of the aquifer lie beneath the urbanised and agricultural area. The second test area was Mura valley's unconfined porous aquifer, which is located in the north-eastern part of Slovenia and is part of Pannonian basin. It is a source for drinking water for about 70.000 people. The aquifer is shallower, the average thickness is 17 m, the groundwater recharges mainly from precipitation (only about 20% from the river Mura) and most of the aquifer lies beneath the agricultural area. Mean annual temperature (1971-2000) is 9.6 °C and mean annual precipitation (1971-2000) 787 mm.

As the groundwater levels show a decreasing trend over the last few decades, especially in the Mura valley, the question arises whether this is due to human interventions, e.g. groundwater pumping surpassing groundwater recharge rates or climate-related decrease in groundwater recharge.

Methods and results

Temperature and precipitation daily data were obtained from RCM models, based on EOBS data base: RegCM3 and ALADIN. A greenhouse gas emission scenario, the A1B scenario was used with these models for the two future periods: 2021-2050 and 2071-2100. RCM predictions were adjusted to local observations by the quantile mapping method approach (Bergant & Muri 2010). The increase in air temperature was the largest in the warm part of the year, particularly in the summer for both test areas. Precipitation data manifested a high degree of ambiguity in the future periods, but the model simulations agreed on a general trend pointing to less precipitation in the summer. Modelled data also indicated trends in the direction of longer duration of dry spell and greater maximum daily rainfall.

As Ljubljana field aquifer is extensively fed from the river Sava (50%), impacts of surface water flow regime was expected to affect groundwater in the future. For this purpose, future river discharges were calculated for both, Sava and Mura river, as linear correlation between standardized variables, the different combinations of cause-effect relationship and considered hydrometeorological time series (Prohaska et al. 2011). For independent variables, known values of time series are taken: discharge and different climatic functions, such as precipitation, mean air temperature, humidity, vapour pressure, etc. With assumption that the river bed would not change in the next 100 years, results had shown that trends of mean annual discharges would not change significantly, whereas the variability would increase - higher values of maximum and lower values of minimum discharge are expected.

The water balance for the past (1971-2000) and two above-mentioned future periods were calculated with the GROWA-SI model (Kunkel & Wendland, 2002). The GROWA-SI model consists of several modules for determining the real evapotranspiration, total runoff, direct runoff and groundwater recharge. The input data for the model are climate parameters modelled with ALADIN and RegCM3. Mean annual groundwater recharge for the period 1971-2000 varies from 41 Mm^3/year (ALADIN) to 43 Mm^3/year (RegCM3) for the Ljubljana field aquifer. Considering the recharge from the river Sava as well, total infiltration is about 84 Mm^3. In the period 2021-2050 the total (precipitation and river) infiltration into groundwater is estimated to increase from today's 84 Mm^3/year to 89 Mm^3/year. In the period 2071-2100 this quantity should, according to RegCM3 decrease to 86 Mm^3/year and even to 75 Mm^3/year according to ALADIN. For the Mura valley, mean annual groundwater recharge from precipitation varies from 63 Mm^3/year (ALADIN) to 58 Mm^3/year (RegCM3) (1971-2000), taking into account the Mura river, total infiltration is about 75 Mm^3/year. In the period 2021-2050 the total (precipitation and river) infiltration into groundwater is estimated to 73 Mm^3/year according to both climate models. In the period 2071-2100 the groundwater recharge will be reduced to 48 Mm^3/year (ALADIN) or to 75 Mm^3/year (RegCM3).

Discussion and Conclusions

Water balance results have shown decrease of groundwater recharge in the Ljubljana field as well as in the Mura valley in the future. In the period 2021-2050 the groundwater recharge will decrease up to 10% and in the period 2071-2100 up to 15%. This could also be a socio economic and political issue, since already now there is a great competition for water, mainly among public water supply and agriculture, especially in summer months.

It could be concluded, from the current available groundwater data, that the anthropogenic activities modify the observed aquifer areas, already, impact the hydrological balance, reduce the aquifer recharge, influence the groundwater flow characteristics, change the water source availability and restoration and influence the quality of groundwater, whereas agricultural activities impact the water quality. If to all this, the climate variability and change through recharge processes due to climate changes is added, significant changes in the availability of groundwater could be expected in the future, especially in the areas where groundwater is already stressed.

Acknowledgments

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