Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 97 (2016) 179 – 185

Energy Procedia

European Geosciences Union General Assembly 2016, EGU Division Energy, Resources & Environment, ERE

Assessment of seasonal aquifer thermal energy storage as a groundwater ecosystem service for the Brussels-Capital Region: combining groundwater flow, and heat and reactive transport modeling

Christian Anibas[a,]*, Janik Kukral[a], Mathias Possemiers[b], Marijke Huysmans[a,c]

[a]*Vrije Universiteit Brussel (VUB), Department of Hydrology and Hydraulic Engineering, Pleinlaan 2, 1050 Elsene, Belgium*
[b]*AGT nv., Kontichsesteenweg 38, 2630 Aartselaar, Belgium*
[c]*KU Leuven, Department of Earth and Environmental Sciences, Celestijnenlaan 200E, 3001 Leuven, Belgium*

Abstract

Seasonal aquifer thermal energy storage and recovery (ATES) help urbanized areas to contribute to their energy demands. We assess the potential of ATES in the Brussels-Capital Region, Belgium with groundwater flow, heat and reactive transport models. Situated in the phreatic Brussels Sand aquifer, they indicate that ATES systems are unfeasible for hydraulic conductivities of $4.2e^{-6}$ ms^{-1}. At low groundwater flow velocities however, ATES are feasible for hydraulic conductivities of $1.4e^{-4}$ ms^{-1}. Iron(hydr)oxide precipitation during ATES operation is investigated with reactive transport models. To avoid well clogging groundwater should be pumped only from above or below the aquifers redox boundary.

Peer-review under responsibility of the organizing committee of the General Assembly of the European Geosciences Union (EGU)

Keywords: ATES; groundwater modeling; heat transport; reactive transport; Belgium

* Corresponding author. Tel.: +32-2-629-3635; fax: +32-2-629-3022.
E-mail address: canibas@vub.ac.be

Peer-review under responsibility of the organizing committee of the General Assembly of the European Geosciences Union (EGU)
doi:10.1016/j.egypro.2016.10.048

1. Introduction

Urban areas have a very high energy demand, and therefore place added pressures on ecosystems, the atmosphere, soils and water resources [1]. In the light of global warming, urbanization and an evolving energy system, it is important to let urbanized areas contribute to their own energy demands. One option is to make use of urban aquifers as an ecosystem service. Seasonal aquifer thermal energy storage and recovery (ATES) can assist to more efficiently distribute the used energy between production and demand [2]. This may lead to a decrease in primary energy consumption [1, 3].

ATES, also referred as groundwater heat pumps, are technical systems where a groundwater body acts as a temporal (i.e. seasonal) storage of thermal energy [4]. A typical ATES system consists of one or more wells for the cyclic extraction and the injection of groundwater. During summer, relative cool groundwater is extracted from one well (referred as cold well). At the surface the thermal energy stored in the water is used to cool a building. By this process the water is warmed up before it is injected into the warm well. During winter, the direction of flow reverses, water is now extracted from the warm well. Via the heat pumps and/or heat exchangers the thermal energy is used to heat the building. The cooled groundwater is consequently injected into the cold well. During the next summer, the described cycle starts over again. Most ATES systems operate with small temperature differences of $\Delta T<15°C$ between warm and cold wells; warm wells remain at around 20-25°C while cold wells are limited to ca. 3-5°C. ATES systems are especially suitable for urban areas where office buildings, schools, hospitals and shopping malls have a high demand for heating and cooling power.

The numbers of ATES systems are increasing, further growth is expected in the future. The Netherlands are a leading country in ATES application, where the number of ATES systems has grown from around 30 installations in 1995 to 200 in 2000 and more than 2000 in 2012 [5]. Significant growth rates are also reported in other European countries like Switzerland, Sweden, Germany and in the US [6-8].In some regions they are widespread enough to have recognizable energetic and economic influence. This stimulates scientific investigations on the potential, limitations and recognized problems of ATES operation.

Belgium does not yet make efficient use of its shallow geothermal resources. Both the applied geothermal capacity (i.e. ≈ 20 times less than in the Netherlands) and the growth rate are moderate. The northern region of Belgium, Flanders, facilitates the majority of the countries ATES systems with about 20 large systems (>250 kW) operational in 2011. This is much less than the Netherlands, but a growing interest for ATES is nevertheless indicated. Especially in urbanized areas like the Brussels-Capital Region where a considerable potential for ATES systems exists.

Despite this increase, the presence of ATES systems in Belgium concerns public drinking water companies and environmental regulators about their potential impact on groundwater quality. The aquifer presented in this paper is prone to well clogging because of iron(hydr)oxide precipitation [9]. To date, ATES suitability in the Brussels-Capital Region was only based on geology [10], where only a relative small fraction of the subsurface meets the conditions for ATES (i.e. the presence of relatively thick, geologically and geochemically homogeneous aquifers). This former study, however, did not take into account the hydrology, heterogeneity, or varying saturated thickness of the aquifer; nor were groundwater flow velocities or the induced hydraulic head changes due to ATES operation included. Detailed coupled groundwater flow and heat transport models are therefore needed. The general objective of this research project is to assess the potential and the risks of ATES as an ecosystem service for the Brussels-Capital Region in Belgium in a modeling study. The presented framework applies coupled numerical groundwater flow, heat transport and reactive transport models. This allows for the suitability of the aquifer for ATES to be investigated and potential risks, like well clogging, to be addressed.

2. Hydrogeology of the Brussels Sand Formation

The Brussels-Capital Region has a pronounced topography, where the region east of the Zenne River is covered by an elevated plain which is intersected by several streams and their alluvial lowlands (Fig. 1). A VITO [10] report concluded that the Brussels Sand Formation has a good potential for ATES systems. This formation is present in the eastern part of the Brussels-Capital Region, its western limit is the Zenne River valley. The Brussels-Capital Region is crossed from southwest to the northeast also by smaller streams, including the Woluwe River. They eventually