A comparison between hydrogeological modelling results and literature groundwater ages for shallow and deep aquifers in northern Belgium

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Introduction
Groundwater flow and contaminant transport models have been developed in the framework of the environmental impact assessment of potential future radioactive waste disposal facilities in north-eastern Belgium (Fig. 3). These groundwater flow models encompass both shallow unconfined (Fig. 2) and deep confined aquifers (Fig. 3). Since a lot of information on the hydraulic conductivity and recharge of these models, measured groundwater heads are reproduced satisfactorily (Gedeon 2008; Vandersteen et al. 2012). Observations concerning groundwater age might however still reduce the uncertainty on the transport simulations considerably. In this study, two regional models are used to provide quantitative estimates of the groundwater age in different parts of the studied aquifers. The results are compared with literature data for the same aquifers, and any correspondences or differences are discussed. Further investigations are proposed on the basis of these results.

Methods
- Groundwater flow models
  - Developed in MODFLOW (Harbaugh, 2005).
  - Geometry of geological layers is mainly based on Welkenhuysen et al. (2012), Meyus (1998), and Gedeon and Wernaers (2003).
  - Calibrated using data from different piezometric networks (Labat, 2011).
  - Age estimation using groundwater transport modelling: mean arrival time derived from the breakthrough curve of unit concentration recharge water.
  - Literature data for groundwater ages were found in Coetsiers & Walraevens (2009), Blaser et al. (2010), and the PHYMDL project report (Marivot et al. 2000).

  - Deep Aquifer Model
    - DAP
    - Deep confined freshening aquifer system consisting of an alternating sequence of marl to Cenomanian clay and sand deposits.
    - Strong influence of groundwater abstraction during the last 60 years.
    - Age range up to 850 ka.
    - Groundwater dating
      - Blaser et al. (2010)
      - Samples from depths between 20 – 190 m.
      - Conventional 14C ages: 4.5 – 10 ka.
      - Correction for calcite dissolution, methanogenesis and oxidation of organic matter, matrix.
      - Tertiary concentrations below detection limit (100 T.U.).

- Deep Aquifer Model
  - Groundwater ages predicted by the model, in comparison with the chemically derived ages. Indeed, more recent local studies show that this aquitard influences the hydrological system more than initially thought (Gedeon et al. 2011; Rogiers et al. 2012).

Discussion and conclusions
Overall, there seems to be a linear correlation between the chemically-derived and modelled groundwater ages. The age of young groundwater is apparently underestimated in the models, and the age of old groundwater seems to be overestimated. The groundwater models used for age estimation were not originally developed for this purpose, nor for making accurate predictions at most of the groundwater sampling locations. Hence, considerable bias might exist for the derived ages. The overestimation of hydraulic conductivity of an aquitard within the Neogene Aquifer model might however explain the relatively young ages predicted by the model, in comparison with the chemically derived ages. Indeed, more recent local studies show that this aquitard influences the hydrological system more than initially thought (Gedeon et al. 2011; Rogiers et al. 2012).

The age dating methods used in the cited papers do not account for mixing of groundwater, and implicitly assume a piston flow model. For asymptotic decay methods, this leads to considerable overestimation of groundwater age (Bethke & Johnson, 2008), which could explain the higher age discrepancies observed in this study. Artificial connection to shallow aquifers would be another possibility, as indicated by the exploratory Tritium measurements. Further investigations in the discussed aquifers should focus on the integration of reactive transport modelling with multiple age tracers, including linear accumulation methods. Moreover, in the last few decades, experimental techniques have developed considerably, with the introduction of new tracers that have not been used or tested yet for the aquifers considered in this study, such as CFC, SF6 and 9He. This approach should allow to move beyond the classical piston flow model interpretations, and to condition the developed models with hard data.

References

Fig. 2: Regional modelling of the confined aquifers below the Boom Clay in NE-Belgium. Geology, hydrogeology and hydrology of the Boom Clay and the underlying aquifers. (NAM model).

Fig. 3: Conceptual profile through the Oligocene and Ledo-Pliocene-Brusselian aquifer systems (DAP model).

Fig. 4: Scatterplot of chemical vs modelled groundwater ages.