

Estimation of hydrodispersive characteristics of the alluvium aquifer of the Loiret river

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ABSTRACT

A long duration pumping test (7 days) was coupled with a converging radial flow tracer test in the Loiret alluvial aquifer, which overlies the very productive Beauce limestone. The interpretation of the long duration pumping test on an observation well, 33 m away from the pumping well, shows that the storage coefficient is about 2.1×10^{-3} , typical of a confined pressure transfer. The interpretation of the tracer test, of which 60 % of the mass was recovered, with a single-layer model made possible to determine a kinematic porosity of 2.3 % as well as a dispersivity of 0.38 m (1/86 of the transport distance), for a maximum speed of 22 m/d and an average speed of 11 m/d. These results suggest that the pumping is mobilizing water from the semi-confined layer of the Beauce limestone while the transfer of tracer remained in the unconfined alluvial layer.

Context

As part of the research project CENARI-O ("Connaissance des Echanges entre Nappes et Rivières - Val d'Orléans" / "Study of exchanges between groundwaters and rivers in the Val d'Orléans") funded by the Région Centre-Val de Loire, which aimed at better characterizing the relationship between groundwater and surface water, hydrogeological investigations - pumping test and tracer test - were carried out in order to develop knowledge of the Loiret river and the associated aquifer system in the commune of Saint-Pryvé-Saint-Mesmin (France).

The Loiret is a short river (13 km) which meets the Loire river downstream the city of Orléans. Its flow is essentially generated by a series of resurgences in several springs which originate from partial losses of the Loire river, upstream of this city, in a karst network developed on the first 20 meters of the Beauce limestone (Binet et al., 2010; Jourde et al., 2018). The limestone is covered in the "Val d'Orléans" by 5 to 10 m of alluvium in hydraulic connection. The Loiret river imposes its fluctuations there, mainly coming from flow variations in the Loire river losses.

Method

The tracer test was carried out between two boreholes in the alluvium layer, 4 days after the implementation of a long duration pumping test at a flow rate of $7 \text{ m}^3/\text{h}$, that is to say in stabilized converging radial flow conditions. 18 g of sodium naphthionate were injected briefly (Dirac) into a second well of the same depth and 33 m away.

Equipment and measurements

A GGUN-FL 30 fluorometer was installed in the pumping well with an acquisition interval of 5 minutes. Automatic sampling for spectrofluorimetric analysis was not possible due to the excessive depth of the water level. In the absence of such sampling and analysis, the estimation of background noise is made more difficult. The 18 g of tracer were diluted in a 1.5 L water solution, then injected via a rigid tube into the well, and a 20 L flush was applied.

Results

Tracer first appeared 1.7 days after injection, reaching a maximum concentration of 52 µg/L at around 2.8 days. Monitoring ended at around 4.2 days before restitution was complete, due to an unexpected interruption in pumping.

The mass recovered until the pumping test stopped is 10.84 g (out of 18 g injected) which corresponds to a restitution of approximately 60.2 % (knowing that the tracer test had to be stopped before the end of the restitution).

Interpretation

Background-corrected data were interpreted using TRAC software (Gutierrez et al., 2011) available at <http://trac.brgm.fr>. The interpretation was carried out according to a semi-analytical solution corresponding to the convergent radial flow model. We were able to determine the kinematic porosity, of the order of 2.3%, as well as the dispersivity of the order of 0.38 m (i.e. 1/86 of the transport distance). The maximum speed is 22 m/d and the average speed is 11 m/d under these forced gradient conditions.

Interpretation of the pumping test is tricky. Despite a distance of less than 100 m from the Loiret river, the influence of a constant head boundary is not clear. The transmissivity obtained is 1.6×10^{-3} (observation point) and 1.2×10^{-3} m²/s (pumping well). The estimated storage coefficient at the observation point is 2.1×10^{-3} , in disagreement with the idea of an unconfined aquifer in the alluvium and ten times lower than the kinematic porosity.

CONCLUSION

The questions raised by the interpretations of tracer test and pumping test suggest a flow mode more complex than radial flow in an unconfined alluvial aquifer. Pumping could mobilize not only the water in the alluvium but also in the underlying karst limestones, which would explain a rapid transfer of pressure during the long duration pumping test (storage coefficient of 2.1×10^{-3}) and a transfer of mass in the unconfined part of the aquifer (kinematic porosity of 2.3 %).

KEYWORDS:

tracer test ; TRAC software ; pumping test ; radial convergent flow ; hydrodynamic ; hydrodispersive properties ; alluvial ; breakthrough curve ; sodium naphthionate ; analytical modeling ; real velocity ; Loiret ; Beauce limestone ; aquifer ; advection dispersion equation ; dispersion ; dispersivity

REFERENCES

- [1] Binet S., Joodi A., Joigneaux E., Alberic P., A. Gutierrez (2010) Localisation of a reactive transport zone in a saturated karstic conduit deduced from natural and artificial tracer tests. *Advances in Research in Karst Media*, B. Andreo et al. (Ed.) 123-129 DOI: 10.1007/978-3-642-12486-0_19
- [2] Gutierrez A., Klinka T., Thiery D., Buscarlet E., Binet S., Jozja N., Defarge C., Leclerc B., Fecamp C., Ahumada Y., Elsass J. (2013). TRAC, a collaborative computer tool for tracer-test interpretation. *European Physical Journal (EPJ Web of Conferences 50, 03002)* DOI: 10.1051/epjconf/20135003002.
- [3] Jourde, H., Massei N., Mazzilli N., Binet S., Batiot-Guilhe C., Labat D., Steinmann M., Bailly-Comte V., Seidel J.L., Arfib B., Charlier J.B., Guinot V., Jardani A., Fournier M., Aliouache M., Babic M., Bertrand C., Brunet P., Boyer J.F., Bricquet J.P., Camboulive T., Carrière S.D., Celle-Jeanton H., Chalikakis K., Chen N., Cholet C., Clauzon V., Dal Soglio L., Danquigny C., Défarge C., Denimal S., Emblanch C., Hernandez F., Gillon M., Gutierrez A., Hidalgo Sanchez L., Hery M., Houillon N., Johannet A., Jouvès J., Jozja N., Ladouche B., Leonardi V., Lorette G., Loup C., Marchand P., de Montety V., Muller R, Ollivier C., Sivelle V., Lastennet R., Lecoq N., Maréchal J.C., Perotin L., Perrin J., Petre M.A., Peyraube N., Pistre S., Plagnes V., Probst A., Probst J.L, Simler R., Stefani V., Valdes-Lao D., Viseur S., and Wang X. (2018). SNO KARST: A French network of observatories for the multidisciplinary study of critical zone processes in karst watersheds and aquifers. *Vadose Zone J.* 17:180094. doi:10.2136/vzj2018.04.0094