300 years of urbanization in Paris (France) and its impacts on shallow groundwater : evidences from speleothems and water monitoring

Dumont E. (1), Branchu P. (1), Pons-Branchu E. (2), Borst W. (1), Jean-Soro L. (3), Roy-Barman M. (2), Guillerme A. (4), Fernandez M. (4), Foliot L. (2), Thil F. (2), Pétillon G. (1), Douville E. (5), Bordier L. (2)

25-29th September 2016, Montpellier, France, CORUM Conference Center – 43rd IAH congress

Abstract n°2415

1 Introduction

Urbanization is a complex process that can lead to a huge disturbance of both groundwater quantity and quality. Direct recharge can be reduced by impervious surfaces, while other sources of recharges can occur, such as leaks in water supply systems or sewers (Lerner, 2002). Identifying the separate effects of different anthropogenic activities is often impossible because of the multiple sources of disturbance as well as the lack of information on the pre-urbanization period.

2

In the framework of several successive projects (Preservation of Soils of Urban and Road, INSU/EC2CO, Paris 2030) an observatory has been developped on the NE part of Paris (France) and its inner suburbs to study the influence of urbanization on both soil and groundwater. **This study presents the combined use of groundwater monitoring, urban speleothems analysis and historical data for the reconstruction of 300 years of groundwater evolution in the NE part of Paris.**

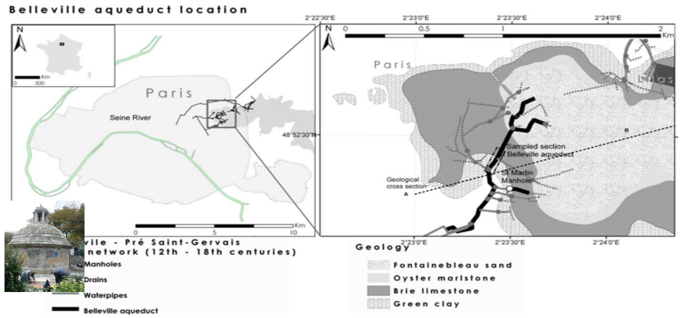


Fig. 1 : Location of the « Northern Spring »

On the study site, two independent groundwater aquifers were first drained in the 1100s to supply the City of Paris with water (“Northern Spring” - **Fig. 1**). Artificial underground water supply systems in calcareous geological context has locally lead to the formation of secondary carbonate deposits, that develop on the walls or on the floor of the aqueducts. **Two speleothems were sampled and dated using two different methods** in order to obtain a robust chronology for these small (29 and 45 mm thick) and very young deposits (<600 based on the probable date of the aqueduct construction) : **laminae counting and U-Th analysis** (**Fig. 2**).

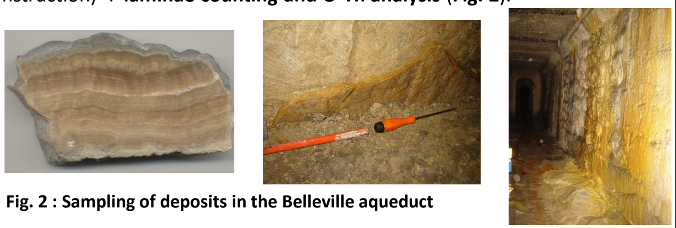


Fig. 2 : Sampling of deposits in the Belleville aqueduct

3

These speleothems recorded groundwater chemistry evolution through their continuous growth over 300 years (Pons-Branchu et al., 2014, 2015). Analyzing heavy metals and major elements compositions as well as isotopic imprints show that **groundwater composition is influenced by anthropic activities through soil infiltration of rain water.** Strong increase in sulfur content during the middle 1800s (**Fig. 3**) suggests a pollution related to gypsum dissolution (Pons-Branchu et al., in progress). As expected, the most recent period (1900 to present) displays high heavy metal contents, but, surprisingly, high heavy metals contents are also observed during the oldest period (1700 – 1750), when land cover was vineyards and orchards, indicating a pre-urbanization pollution (**Fig. 4**).

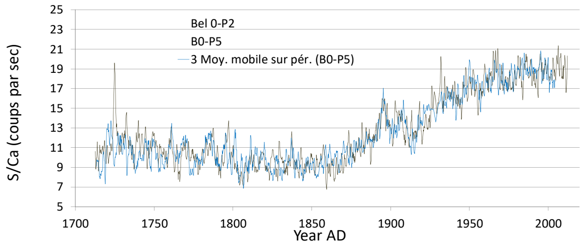


Fig. 3 : Sulfur content in the speleothem : X-Ray µfluorescence (IFSTTAR)

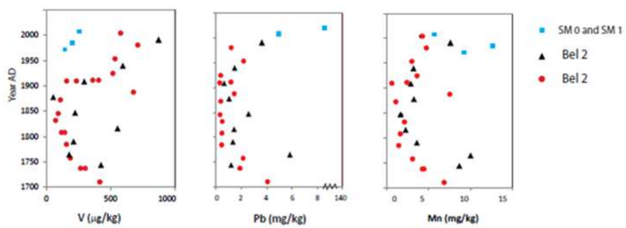


Fig. 4 : Trace elements in Belleville and Saint-Martin samples : V, Pb, Mn (Pons-Branchu et al., 2015, Stoten)

(1) CEREMA: 12 Rue Teisserenc de Bort, 78197 TRAPPES-en-Yvelines Cedex, France AND Rue de l’Egalité Prolongée - BP 134, 93352 LE BOURGET Cedex 319, France

(2) Laboratoire des Sciences du Climat et de l'Environnement (LSCE/IPSL), UMR 8212 CNRS-CEA-UVSQ, Avenue de la Terrasse, 91198 Gif-sur-Yvette Cedex, France

(3) IFSTTAR - Nantes, Route de Bouaye CS4, 44344 Bouguenais.

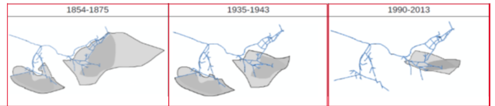
(4) CNAM: HT2S, EA 3716, 2 rue Conté, 75003 Paris , France

(5) GEOPS : Bâtiment 504, Rue du Belvédère Campus Universitaire d’Orsay 91405 Orsay Cedex, France

4

Archive studies and groundwater monitoring permitted to build hydrological budget at 3 key periods of land use evolution (1854-1875 / 1935-1943 / 1990-2013) (**Fig. 5**). Soil sealing rate increased from 2 % (1854) to 84 % (2013) leading to a decrease in natural recharge. Besides, the partial destruction of the historical drainage network reduced the size of the active surface basin area. Thus, urbanization resulted in natural recharge and spring global outflow decreases. However, in the same time, spring daily specific outflow increased, suggesting an anthropic source of groundwater recharge, such as water networks leakage.

Fig. 5 : Hydrological budget evolution from 1854 to 2013



	1854-1875	1935-1943	1990-2013
Soil sealing rate (%)	2	10	84
Active surface basin area (km²)	1.26	0.63	0.15
Active groundwater basin area (km²)	1.7	0.91	0.23
Spring daily specific outflow (L/s/km²)	1.83	3.85	7.36
Rain/outflow rate (%)	11	19	36
Extra urban water -network leakage- (L/s/km²)	0	1.6	5.1
Extra urban water contribution to outflow (%)	0	42	68

5 Conclusions

Dating of the speleothems and analyzing heavy metal composition and isotopic imprint show that several processes linked to progressive urbanization steps seem to have been recorded: **(I) agricultural activity, (ii) road-building, (iii) influence of wastewater collection system (iv) technological innovation.**

Today even with the global soil sealing of the watershed, the historical drainage network is still active. Quantitative and qualitative monitoring of this network indicates that **rainwater infiltration is still occurring but that the main recharge to groundwater comes from the anthropic water network** (sewer, drinking water, …)

6 References

Pons-Branchu E, Ayrault S, Roy-Barman M, Bordier L, Borst W, Branchu P, Douville E, Dumont E. (2015) - Three centuries of heavy metal pollution in Paris (France) recorded by urban speleothems. *Science of the total environment*, 15, pp 86–96.

Pons-Branchu E., Douville E., Roy-Barman et al., Dumont E., Branchu E., Thil F., Frank N., Bordier L. and Borst W. (2014). A geochemical perspective on Parisian urban history based on U-Th dating, laminae counting and yttrium and REE concentrations of recent carbonates in underground aqueducts. Quaternary Geochronology 24, 44-53.

Lerner, D., 2002. Identifying and Quantifying Urban Recharge: a Review. Hydrogeology Journal, 10(1), 143–152.