Middle Term Evolution of Water Chemistry in a Karst River: Example from the Loue River (Jura Mountains, Eastern France)

J. Mudry, F. Degiorgi, E. Lucot and P.-M. Badot

Abstract Plotting multiyear chemographs in a karst river may display evolutional trends in water quality. In recent decades, different factors could explain for instance phosphate decrease and nitrate increase. In the Jura karst area, different springs and rivers not only exhibit variation of anthropogenic molecule concentrations, but also evolution of major element concentrations, that results in a change in electrical conductivity. Over a 30-year period, average electrical conductivity of the Loue River, which is totally supplied by karst springs, has increased from 260 to 470 μS/cm. Such an 81 % variation is only explainable by increases in major components, i.e. calcium and hydrogenocarbonate ions, which are the almost exclusive by-products of karstification processes in the Jurassic limestones of the Jura Mountains. Indeed, no direct anthropogenic cause may be invoked for such an evolution. An increase of dissolution throughout the system is necessarily correlated to an increase in the carbon dioxide transfer, resulting from an increase in dissolution and/or production rate.

1 Introduction

Generally, hydrochemical datasets of springs and rivers in karst context are used to display either pollutions or global changes. The Loue River, situated in the Jura Mountains (Eastern France) is a well-known river for sport fishery (trout and grayling). Recently, it has been subjected to several severe fish mortality episodes, despite the fact that water meets the chemical quality standards.

These problems led to examine finely the historical records of ionic concentrations and concentrations of various pollutants. These physical and chemical data

J. Mudry (✉) · F. Degiorgi · E. Lucot · P.-M. Badot
Chrono-Environnement, UMR 6249/CNRS University of Franche Comté,
16 Route de Gray, 25000 Besançon, France
e-mail: jacques.mudry@univ-fcomte.fr

© Springer-Verlag Berlin Heidelberg 2015

B. Andreo et al. (eds.), *Hydrogeological and Environmental Investigations in Karst Systems*, Environmental Earth Sciences 1,
DOI 10.1007/978-3-642-17435-3_17

have been collected at the drinking water production plant of the city of Besançon, located at Chenecey-Buillon, in the middle valley of the Loue. No significant pollution episodes, but only gentle incremental variations were displayed. This fact does not argue for a massive pollution, but conversely for a progressive worsening of multi-factor environmental quality.

One of the major historical changes in physical-chemical parameters is an increase in electrical conductivity (Teleos 2002). Fitting a 40 year conductivity dataset with time displays a rough linear relationship (Fig. 1).

2 Global Reasons

Several trends in karst water balance and in subsequent chemical change can be ascribed to global climate change, such as North Atlantic Oscillation (NAO, Knight et al. 2006). But throughout the interested period, no significant trend can be highlighted in the discharge of the river (Villeneuve et al. 2012).

On the other hand, in the period 1970–2006, atmospheric carbon dioxide concentration increased by 17 % from 325 to 380 ppm. This difference cannot explain the synchronous change in electrical conductivity by 81 %, from 260 to 470 µS/cm. Nevertheless, combined with the correlated global climate change, it could be involved in soil modification trends (Jackson et al. 2009).

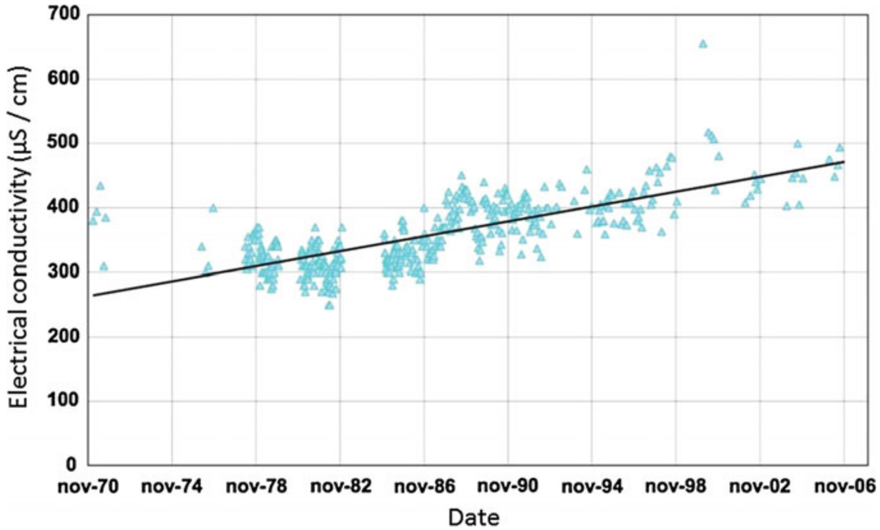

Fig. 1 Evolution of electrical conductivity (Loue River, Chenecey-Buillon). Cond = 0.0156 $t_{(j)}$ − 139.19; R = 0.74 (HS)

3 Pollution Reasons

As a whole, the main indicators of human activities in a watershed show contrasted evolutions in 40 years (Fig. 2).

Nitrate concentration, despite a wide range of variation due to leaching episodes, displays an increasing trend. On average, nitrates increase by 66 %. This increase could be linked to a (moderate) increase of the cattle density in the recharge area, and to a (significant) increase of milk productivity *per capita* (Lambert 2007; Lambert et al. 2010) through the period of interest (Fig. 3).

Indeed, milk production was 5,387 kg per year in 1979 and 7,303 kg in 2000. This increase by 36 % of milk productivity is arithmetically correlated to a 36 % increase of nitrogen in excreta. But passing from 4 to 8 mg/L of nitrogen cannot explain 81 % of conductivity increase: doubling this nitrate concentration is increasing electrical conductivity up to 5 μS/cm only (versus 210 μS/cm observed in the river).

Phosphorus, originating in sewage treatment plants and in manure spreading, displays a trend towards reduction, mainly peaks, because of the improvement of urban sewage collection and treatment. The cases of ammonium and chlorophyll are similar: descending trend for maxima.

No analysed pollutant can be invoked to explain the high conductivity increase of the last 40 years.

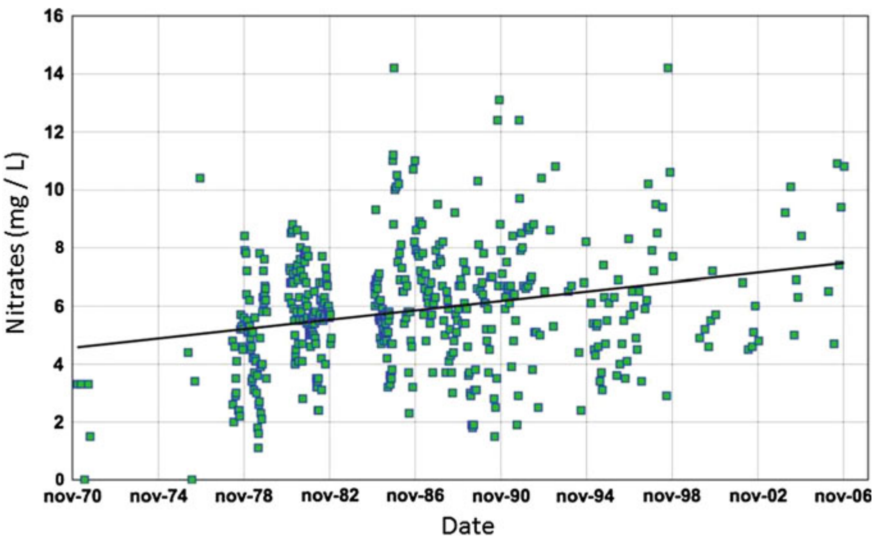

Fig. 2 Evolution of nitrate concentration (Loue River, Chenecey-Buillon)

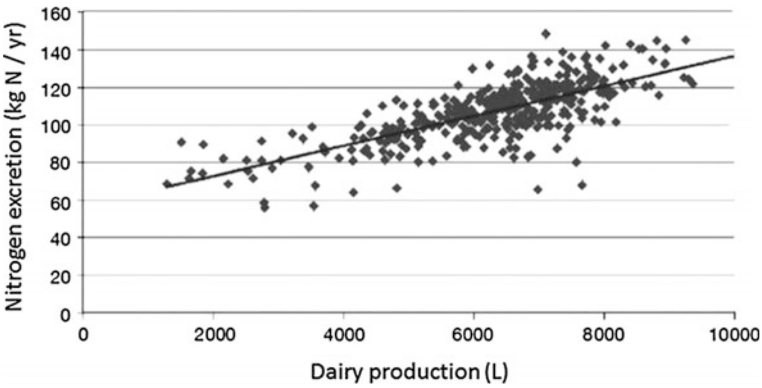

Fig. 3 Estimation of the dairy cow's nitrogen excretion versus milk production (Lambert 2007)

4 Land Use Reasons

What has actually changed in the recharge area during the last 40 years?

Population and correlatively traffic have increased. Sewage collection and treatment are now more efficient. Wood treatment in sawmills and also within the forest use more insecticides and fungicides, but these toxic pollutants cannot explain any calcic-carbonic mineralisation change. But the land use management is quite different today. Grasslands have no more a natural growth; they are deeply ploughed, with a significant consequence: increased reaction surface between soil aggregates, solution and atmosphere. This practice promotes mineralisation of organic carbon, therefore CO_2 production, enabling solid carbonate dissolution.

5 Conclusions

A dramatic increase of electrical conductivity in a karst context with moderate population and economic activity growths cannot be assigned to a sole direct pollution effect. It requires a spatial phenomenon involving massive additional CO_2 production. The present hypothesis is that the soil itself undergoes a loss of organic carbon owed to a change in agricultural practices, involving deep ploughing. This process could also be magnified by global climate change and/or increased atmospheric Carbon dioxide. A balance in soil carbon will support these hypotheses.

References

Jackson RB, Cook CW, Pippen JS, Palmer SM (2009) Increased below-ground biomass and soil CO_2 fluxes after a decade of carbon dioxide enrichment in a warm-temperate forest. Ecology 90(12):3352–3366

Knight JR, Folland CK, Scaife AA (2006) Climate impacts of the Atlantic multidecadal oscillation. Geophys Res Lett 33:L17706. doi:10.1029/2006GL026242

Lambert R (2007) Rejets azotés de la vache laitière en région wallonne. *In*: 14ème rencontre autour des recherches sur les ruminants, 5–6 décembre, Paris, 14

Lambert R, De Toffoli M, Dufrasne I, Hornick JL, Stilmant D, Seutin Y (2010) Towards a revision of the dairy cow's standard for nitrogen production: Justification and what are consequences for soil link rate of dairy farms. Biotechnologie Agron Soc et Environ 14:67–71. http://www.pressesagro.be/base/text/v14ns1/67.pdf

TELEOS (2002) Study of ecological aquatic potentiels écologiques of the 'Natura 2000' sites of the Loue and Lison rivers, DIREN of Franche—Comté, 87p + annexes + atlas. Unpublished (in French). https://www.yumpu.com/fr/document/view/16903417/etude-des-potentiels-ecologiques-aquatiques-des-sites-natura-2000. Accessed 15 March 2014

Villeneuve A, Humbert JF, Berrebi R, Devaux A, Gaudin Ph, Pozet F, Massei N, Mudry J, Trevisan D, Lacroix G, Bornette G, Verneaux V (2012) Expertise report about fish mortalities and cyanobacteria blooms of the Loue river. Study of the functionning of the Loue River and watershed. Report ONEMA, p 32. Unpublished (in French). http://www.esrl.noaa.gov/gmd/ccgg/trends/ Assessed 5 March 2014