Perchlorates in the chalk aquifer of Northeastern France (Marne-Ardennes)
Preliminary results and perspectives

J. Jaunat[(1)]*, P. Ollivier[(2)], D. Hube[(2)], P. Taborelli[(1)], A. Devos[(1)], B. Cances[(1)], X. Morvan[(1)], P. Pannet[(3)], V. Barbin[(1)]

43rd IAH congress, 25-29th September 2016, Montpellier, France, CORUM CONFERENCE CENTER

Abstract n°1550

1. Introduction

Measurements carried out in France revealed the presence of perchlorate ions (ClO_4^-) in groundwater resources, particularly in the North-East of France. Because it is recognized as an endocrine disruptor (toxicity not yet perfectly quantified), French authorities recommends a limit in drinking water about 15 µg/L for adult people (Table 1), thresholds exceeded in some drinking waters distributed in the French Marne county area .

This study aims at precisely identify the origins of ClO_4^- founded in groundwater from the study area and accurate their behavior and transfer modalities in aquifers in a long-term management concern.

2. State of the art and Framework

ClO_4^- mobility properties

Chemically stable + Salts highly soluble + Weakly adsorbable = Extremely mobile

ClO_4^- origins and use

Major Natural occurrences :

- In nitrogen-rich minerals formed in hyper-arid conditions (e.g. Atacama Desert in Chile, desert of New Mexico in United-States);

Anthropogenic occurrences:

- Worldwide exploitation of "Chilean saltpeter" until the mid-20th century as fertilizers;
- Military and commercial applications of ClO_4^- salts. Large quantities used in during the World War I.
- Artificial synthesis since the 1920s.

Study area

Hydrogeology : chalky aquifer part of the Paris Basin; major water resource of the area.

ClO_4^- contamination :

Measurements conducted in 2014 in drinking water networks of the Marne County by the Regional Health Agency (ARS; Table 1 and Figure 1)

Table 1: Contamination condition in the Marne County and recommendations of consummation

Tap water ClO_4^- concentration	French recommendations	Number of town in study area
4 µg.L^{-1} < ClO_4^-	No restrictions	534
4 µg.L^{-1} < ClO_4^- < 15 µg.L^{-1}	Non consumable for Infants and pregnant or nursing women	81
ClO_4^- > 15 µg.L^{-1}	Undrinkable	5

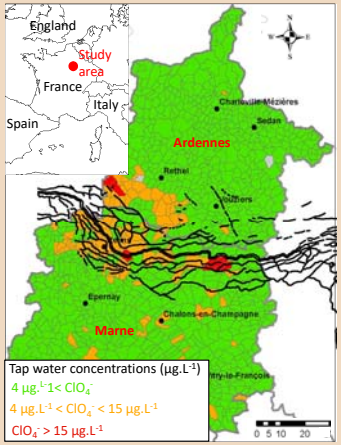


Fig. 1: Concentration of perchlorates (in tap water) and position of 14-18 front lines (black lines) – *modified from ARS Champagne-Ardenne*

3. Objectives and methods

Table 2: Objectives of the study and methods used to reach them

Objectives	Methods	Expected results
- Sources of molecules	Analyses of historical archives	Identification and localization of past and actual potentially emitting activities
- Sources of molecules - Relationships ClO_4^- VS other molecules (nitroaromatics, nitrates, chlorates…)	ClO_4^- and NO_3^- isotopic signal	Different signatures function of the molecule origin
- Sources of molecules - ClO_4^- comportment and transfer in aquifers	Groundwater residence time (CFCs, SF_6)	- Relationships between groundwater age and concentration - Transfer time of the molecules
- ClO_4^- comportment and transfer in aquifers	Monitoring of major and trace elements and of $\delta^{18}O$ $\delta^{2}H$	Hydrogeological and hydrochemical context
- Relationships ClO_4^- VS other molecules	Oxyanions and explosives concentration analyses	Potentially occurrence of not routinely measured molecules

4. Hypotheses and preliminary results : possible ClO_4^- origins

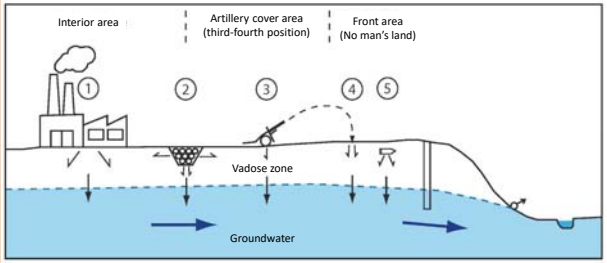
Historical archives study + geographical approaches + groundwater analyses = assumptions about the ClO_4^- origins in the studied area

Agricultural origin

Between 1875 and 1920, France imported large amounts of natural nitrates ($NaNO_3$) from Chile to fertilize the soils. These natural fertilizers are rich in perchlorates, iodates, selenates, etc. The study area is traditionally intensive farming lands.

Military origin

The study area has been permanently marked by the events of the First World War. Geographical analyses of both groundwater ClO_4^- concentrations and the front line positions during the 14-18 conflict allows to assume a link between the World War I activities and the actual concentrations (Figure 1). The different processes that could have implemented the contamination are summarized in Figure 2.



(1) Pyrotechnic factory (2) Ammunition repositories and/or destruction (3) Artillery battery (4) Impact area (5) Burried non explosed ammunition

Fig.2: Conceptual model of groundwater contamination by military activities

5. Conclusion and Perspectives

To help the water operators to manage this crucial issue for long term, the assumptions of contamination will be ascertain and the strategy developed in table 2 will be performed over the three next years.

From left to right:

- Deposit of shells (*www.delcampe.net*)
- Deposit of cartridge case (*National Library of Scotland*)
- Shells fired unexploded warhead in Marne (*Devos*)
- Trench bomb in Aisne (*Cardem-Pyro*)

Acknowledgments

This study is financially supported by : Agence de l'eau Seine-Normandie, BRGM, Reims Métropole, Agence Régionale de Santé Grand-Est.

(1) University of Reims Champagne-Ardenne, EA 3795 – GEGENAA, 2 esplanade R. Garros, 51100 Reims, France, Jessy.jaunat@univ-reims.fr
(2) BRGM, 3 Avenue C. Guillemin, BP 36009, 45060 Orléans Cedex 2, France
(3) BRGM, Regional service, 12 Rue C. Ader, BP137, 51685 Reims Cedex 2, France