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High $^{36}Cl/Cl$ ratios in Chernobyl groundwater

Céline Roux [a, b, *], Corinne Le Gal La Salle [a, c], Caroline Simonucci [b], Nathalie Van Meir [b], L. Keith Fifield [d], ASTER Team [a, 1] Olivier Diez [b], Sylvain Bassot [b], Roland Simler [e], Dmitri Bugai [f], Valery Kashparov [g], Joël Lancelot [a, c]

[a] Aix-Marseille Université, CNRS-IRD-Collège de France, UM 34 CEREGE, Technopôle de l'Environnement Arbois-Méditerranée, BP80, 13545 Aix-en-Provence, France

[b] Institute for Radioprotection and Nuclear Safety, PRP-DGE/SRTG, BP 17, F-92262 Fontenay-aux-Roses, France

[c] Université de Nîmes, Laboratoire de Géochimie Isotopique (GIS), 150 rue George Besse, 30035 Nîmes, France

[d] Department of Nuclear Physics, Research School of Physics and Engineering, The Australian National University, ACT 0200, Australia

[e] Laboratoire d'Hydrologie d'Avignon, UMR EMMAH 11144 INRA, Université d'Avignon, 84000 Avignon, France

[f] Institute of Geological Sciences, 55-b, Gonchara Str., Kiev 01054, Ukraine

[g] Ukrainian Institute of Agricultural Radiology, UIAR NUBiP of Ukraine, Mashinobudivnykiv str. 7, Chabany, Kyiv-Svjatoshin, Ukraine

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ABSTRACT

After the explosion of the Chernobyl Nuclear Power Plant in April 1986, contaminated material was buried in shallow trenches within the exclusion zone. A ^{90}Sr plume was evidenced downgradient of one of these trenches, trench T22. Due to its conservative properties, ^{36}Cl is investigated here as a potential tracer to determine the maximal extent of the contamination plume from the trench in groundwater. $^{36}Cl/Cl$ ratios measured in groundwater, trench soil water and leaf leachates are 1–5 orders of magnitude higher than the theoretical natural $^{36}Cl/Cl$ ratio. This contamination occurred after the Chernobyl explosion and currently persists. Trench T22 acts as an obvious modern point source of ^{36}Cl, however other sources have to be involved to explain such contamination. ^{36}Cl contamination of groundwater can be explained by dilution of trench soil water by uncontaminated water (rainwater or deep groundwater). With a plume extending further than that of ^{90}Sr, radionuclide which is impacted by retention and decay processes, ^{36}Cl can be considered as a suitable tracer of contamination from the trench in groundwater provided that modern release processes of ^{36}Cl from trench soil are better characterized.

1. Introduction

After the explosion at the Chernobyl Nuclear Power Plant in April 1986, debris, contaminated organic matter and contaminated soils were buried in about 800 shallow trenches within the exclusion zone. This clean-up operation aimed at reducing radiation exposure and atmospheric remobilization of radionuclides. These trenches were dug in a permeable sandy formation, favorable to radionuclide migration through soils and in groundwater. To monitor these migrations, one of these trenches, trench T22, was chosen as a pilot site (Chernobyl Pilot Site) since 1999, in the frame of a collaborative program between the French Institute for Radiological Protection and Nuclear Safety (IRSN), the Ukrainian Institute of Agricultural Radiology (UIAR-NUBiP) and the Institute of Geological Sciences (IGS). Studies were intensified in 2008 through the funding of the TRASSE research group (on Radionuclide Transfers to the Soil, the ground and the Ecosystems), based on a collaboration between IRSN and the French National Center for Scientific Research (CNRS).

A ^{90}Sr plume was shown in groundwater downgradient of the trench, with volumetric activities reaching 1000 Bq L^{-1} (2×10^{-9} mmol L^{-1}) 15 m from the trench (Dewiere et al., 2004). Because of the reactivity of strontium, ^{90}Sr migration is delayed by sorption processes (Szenknect, 2003; Dewiere et al., 2004; Bugai et al., 2012a). Less reactive radionuclides, not impacted by such processes, may have migrated over longer distance.

* Corresponding author. Aix-Marseille Université, CNRS-IRD-Collège de France, UM 34 CEREGE, Technopôle de l'Environnement Arbois-Méditerranée, BP80, 13545 Aix-en-Provence, France.

E-mail addresses: celine_roux@live.fr (C. Roux), corinne.legallasalle@unimes.fr (C. Le Gal La Salle), caroline.simonucci@irsn.fr (C. Simonucci), nathalie.vanmeir@gmail.com (N. Van Meir), Keith.Fifield@anu.edu.au (L.K. Fifield), Olivier.DIEZ@irsn.fr (O. Diez), Sylvain.BASSOT@irsn.fr (S. Bassot), roland.simler@univ-avignon.fr (R. Simler), dmitri.bugay@gmail.com (D. Bugai), vak@uiar.kiev.ua (V. Kashparov), joel.lancelot@unimes.fr (J. Lancelot).

[1] Didier L. Bourlès (bourles@cerege.fr), Maurice Arnold (arnold@cerege.fr), George Aumaître (aumaitre@cerege.fr), Karim Keddadouche (keddadouche@cerege.fr).

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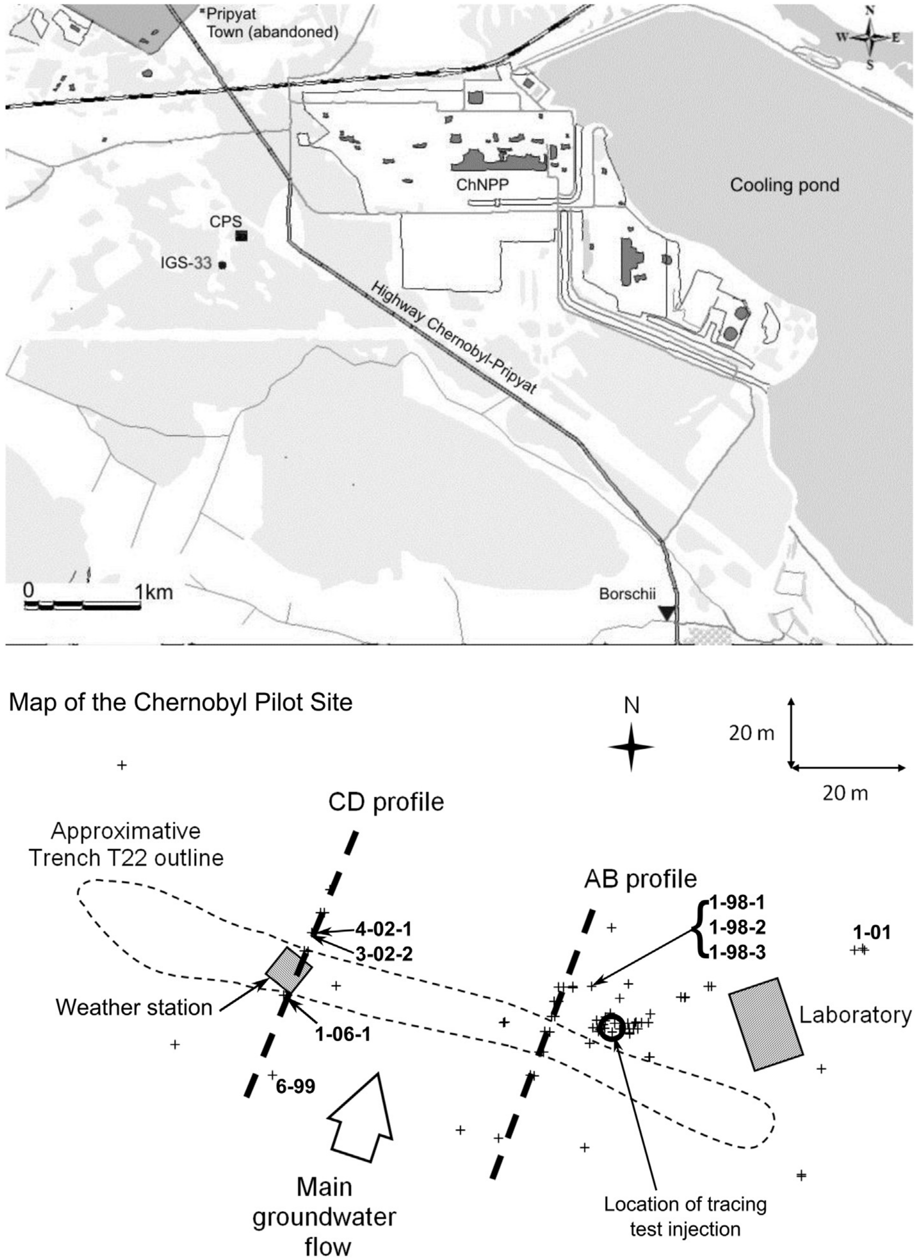

Fig. 1. Location and map of the Chernobyl Pilot Site (CPS). Piezometer locations are symbolized by crosses. For more details about piezometers on the CD profile, see Fig. 2.

Due to its conservative properties, chloride (Cl^-) is not impacted by sorption or other water–rock interaction processes in the aquifer and could be a suitable tracer of to characterize the maximal extent of radionuclide contamination from the trench. More specifically, its radioisotope chlorine-36 (^{36}Cl) is a product of nuclear activity and has most likely been released during the Chernobyl accident: Chant et al. (1996) showed high $^{36}Cl/Cl$ in lichens linked to the accident in Ukraine, Belarus and Russia. Moreover, ^{36}Cl is of interest at such a time scale as its radioactive decay is negligible (half-life: $3.01 \times 10^5 \pm 0.04 \times 10^5$ years; Endt and Van der Leun, 1973). However, the investigation of the maximal extent of the contaminant plume using ^{36}Cl as a tracer might be complicated. For instance, 25 or so years after the explosion, ^{36}Cl pulse linked to the Chernobyl explosion might have migrated outside the studied area or be so diluted that this pulse is not observable anymore.

This study aims to determine if ^{36}Cl is a suitable tracer of the contamination from trench T22 under non reactive conditions through the characterization of ^{36}Cl content in Chernobyl Pilot Site groundwater.

2. Study site settings

The Chernobyl Pilot Site (CPS) is located 2.5 km South-West from the Chernobyl Nuclear Power Plant (ChNPP) (Fig. 1). These facilities are installed on the first alluvial terrace and on the right bank of the Prypiat River, located at the top of sedimentary formations covering the North-western slope of the Ukrainian shield (Matoshko et al., 2004). The shallow 30-m-thick aquifer is composed of two facies, a 4-m-thick homogeneous aeolian layer underlain by a heterogeneous alluvial layer, both favorable to