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RADIOCARBON DATING OF MODERN GROUNDWATER: THE ROLE OF THE UNSATURATED ZONE

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Abstract

Biological and physical processes occurring in soils may lead to significant isotopic changes between the isotopic compositions of atmospheric CO_2 and of soil CO_2. Also, during water and gas transport from the soil surface to the water table, isotopic changes likely occur due to numerous physical processes such as gas production and diffusion, water advection, and gas-water-rock interactions. In most cases, these changes are not included in the correction models developed for groundwater dating, whereas they can significantly impact the calculation of the ^{14}C age (Fontes, 1992; Gillon *et al.*, 2009). We explore the role of these processes using:

i) experimental data from two aquifer sites (Fontainebleau sands and Astian sands, France),

ii) a distributed model to simulate the ^{14}C activities of soil CO_2,

and iii) numerical simulations in order to highlight the role of the physical processes.

The ^{13}C content in soil CO_2 showed seasonal variations and highlighted the competition between CO_2 production and CO_2 diffusion. Their respective contributions played a significant role in defining the isotopic composition of CO_2 at the water table. On both study sites, variations of the ^{14}C activity in soil CO_2 reflect the competition between the fluxes of root derived-CO_2 and of organic matter derived-CO_2. Since the nuclear weapon tests in the fifties and sixties, soil CO_2 became significantly depleted in ^{14}C compared to atmospheric CO_2. Models that take into account this ^{14}C depletion in soil CO_2 for dating modern groundwater would lead to apparent younger ^{14}C ages than models that only consider the ^{14}C activity in atmospheric CO_2. Moreover, since 2000-2005, the inverse effect is observed as soil CO_2 is enriched in ^{14}C compared to atmospheric CO_2 (Gillon *et al.*, in revision).
Therefore, we conclude that the isotopic composition of CO_2 at the water table have to be taken into account for the dating of modern groundwater. This requires a systematic sampling of soil CO_2 and the measurement of its ^{13}C and ^{14}C contents. We used this information in a numerical simulation to calculate the evolution of isotopic composition of CO_2 from the soil surface to the water table. This simulation integrated physical processes in the unsaturated zone (e.g. CO_2 production and diffusion, water advection, etc.) and gas-water-rock interactions.

References

1. Fontes (1992) *Radiocarbon After Four Decades*, 242-261
2. Gillon *et al.* (2009), *Geochim. Cosmochim. Acta* **73**, 6488-6501
3. Gillon *et al.*, *geoderma*, in revision