Review of environmental multi-tracer sensitivity to groundwater discharge in river

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Abstract

Assessing the distribution of groundwater inflow to small watersheds is of utmost interest to appreciate the sensitivity of humid zones to environmental changes. However, this distribution is poorly constrained because the resolution on river flow measurements is generally low. Different environmental tracer experiments have been proposed during the last decade [1]. In this work, we investigate the significance of $\delta^{18}O_{water}$, $\delta^{2}H_{water}$, $\delta^{13}C_{TDIC}$, $A^{222}Rn$ coupled with *in situ* measurements (Q, T°, EC, pH, alcalinity) to better understand groundwater inflow to rivers. These tracers have been chosen as they may depict signals significantly different from groundwater to surface water. Here, we focus on processes and kinetics that sustain tracer evolution in surface waters.

The experimental site is a small watershed (219 km²) located in northern France. The Hallue River is 15 km long and flows over the Chalk aquifer. Stream flow was measured manually using a velocimeter and reflects variations in groundwater discharge along the river length. T, EC, pH and alkalinity were measured *in situ* at 11 locations along the Hallue River. Sampling for $\delta^{18}O_{water}$, $\delta^{2}H_{water}$, $\delta^{13}C_{TDIC}$ and $A^{222}Rn$ was performed in different glass bottles on the 11 locations with a peristaltic pump. Analyses of $\delta^{18}O_{water}$ and $\delta^{2}H_{water}$ were done in the IDReau laboratory (University Paris Sud, France) whereas the others were made at the "Département des sciences de la Terre et de l'atmosphère de l'UQAM" and at the GEOTOP (laboratory). The results of $\delta^{18}O_{water}$ and $\delta^{2}H_{water}$ show that there is no evaporation of the river water. The correlations between ^{222}Rn, CE and $\delta^{18}O_{water}$ and between $\delta^{13}C_{TDIC}$ and pH are high. ^{222}Rn and $\delta^{13}C_{TDIC}$ are anti-correlated and respond rapidly to groundwater inflow to the river. As a result, ^{222}Rn and $\delta^{13}C_{TDIC}$ processes are modeled using a diffusion exchange approach discretized along the river, as suggested by Cook et al. (2006) for ^{222}Rn [2]. The model fits very well the evolution of ^{222}Rn. Yet, the sensitivity of the model is too low for $\delta^{13}C_{TDIC}$.

[1] Gleason and al. (2009), Water Resour. Res. [2] Cook and al. (2006), Water Resour. Res., 42.

The Lower St. Lawrence Estuary: A suitable analogue for OMZs?

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When the rate of oxygen consumption in water exceeds the rate of supply, the oxygen concentration decreases and may reach levels that threaten the survival of many aquatic organisms. Waters with such low oxygen levels are termed severely hypoxic ($[O_2] < 62.5$ $\mu mol\ L^{-1}$).

The dissolved oxygen concentration in the deep water of the Lower St. Lawrence Estuary (Eastern Canada) has progressively decreased during the last century, concomitent with an increase in temperature. The severely hypoxic threshold was reached in the early 1980s where it has hovered ever since [1].

Using a 2D diffusion-advection model for oxygen, we examined the causes of large-scale hypoxia in the bottom waters (> 150 m depth) of the Lower St. Lawrence Estuary [2] and estimated the volumetric evolution of these hypoxic waters in response to further changes in the boundary conditons (biogeochemical properties of the waters that enter the estuary from the North Atlantic Ocean). The physics of the system and the source water properties were identified as the main cause of oxygen depletion and shown to control the oxygen distribution pattern in the deep water column [2]. Preliminary results on the evolution of hypoxia reveal that a ~2°C increase of the bottom water temperature would cause widespread anoxia throughout the Lower St. Lawrence Estuary and into the western Gulf.

[1] Gilbert et al. (2005) *Limnology & Oceanography* **50**, 1654-1666.
[2] Lefort et al. (submitted) *JGR-Oceans*.