Hydrochemical and isotope study of groundwater contamination by fecal microbes

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In order to better understand the source (s) and behavior of the norovirus and other fecal microbes in groundwater systems we performed a hydrochemical and environmental isotope study in conjunction with a microbiological survey on total coliform, *E. coli*, fecal bacteria, coliphage and norovirus. In the study area with known norovirus contamination, groundwater samples were collected from 21 existing household wells and 3 multi-level monitoring wells (MLWs) installed around a latrine. The detection rate of the norovirus was high (10-19%) in household wells. Cl versus Cl/Br plots suggest that fecal microbes and potentially associated pollutants such as nitrate, chloride and sulfate are likely derived from septic effluents and animal wastes. Nitrogen and oxygen isotope ratios of nitrate in 21 groundwater samples [$\delta^{15}N_{nitrate}$ = 7.6 to 18.9‰ (avg. 13.5‰), $\delta^{18}O_{nitrate}$ = 3.6 to 13.4‰ (avg. 6.7‰)] also indicate the origin of nitrate from manure and/or sewage. Hydrochemistry data obtained from MLWs indicated the existence of one or two distinct reduction zones where denitrification occurred. In addition, groundwater from MLWs showed the frequent and considerable detection of total coliform and fecal bacteria. Detection rates of *E. coli*, coliphage and norovirus were negligible, possibly indicating that they are preferentially absorbed onto soil particles in unsaturated or saturated zones. Combined with local geologic features, we suggest that iron (hydro-)oxides in subsurface soils play a role as a sorbent of microbes. The results of this work will be helpful to evaluate the vulnerability of groundwater to fecal contamination, which can accompany norovirus and other fecal microbes.

Pb in a deep sea coral: Transfer of anthropogenic Pb to the deep North Atlantic Ocean over the last 500 years

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Pb in the deep ocean depends on transit time distributions because its concentration and isotope composition in the surface ocean have varied significantly over time in response to anthropogenic Pb emissions. However, the use of Pb as a tracer has been limited by the lack of data in the ocean interior both in time and space. In this study, a ~500 year history of the evolution of Pb and Pb isotope ratios in the interior North Atlantic Ocean is established from a deep sea coral *E. rostrata* which was collected from ~1410m depth on the north Bermuda slope.

Coral Pb concentrations range between 1.1-4.5 nmol Pb/mol Ca from the early 16th century to the 17th century, and Pb isotope ratios ($^{206}Pb/^{207}Pb$ = 1.21, $^{208}Pb/^{207}Pb$ = 2.495) in this period agree with those found in pelagic sediments of the western North Atlantic Ocean. Slightly increased Pb/Ca ratios (~7 nmol Pb/mol Ca) are found between 1740s and 1860s, and the ratio increases rapidly from 1860s to 1997 by a factor of four. Both $^{206}Pb/^{207}Pb$ and $^{208}Pb/^{207}Pb$ ratios decrease from the mid-18th century as the Pb concentration increases, probably due to the penetration of anthropogenic Pb into the deep sea, which has lower $^{206}Pb/^{207}Pb$ and $^{208}Pb/^{207}Pb$ isotope compositions than natural Pb in this region. Comparison of this data to the 200-yr-record of surface Pb data from Bermuda corals shows that the transit time of Pb from the surface to the coral growth site is about 25 years. This estimate is consistent with that from radiocarbon measurements in the same coral. Reconstructed $\Delta^{14}C$ values also show that the bomb radiocarbon signal appears 20-25 years later than its first appearance in the surface ocean near Bermuda. However, the rise of $\Delta^{14}C$ is not as rapid in the deep as it is in the surface, potentially allowing us to reconstruct the relative effects of transport and diffusion on tracer movement from the surface to the intermediate North Atlantic Ocean.