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Spatial analysis of sedimentary controls on submarine groundwater discharge

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Radium is considered to be an excellent tracer of submarine groundwater discharge (SGD). The four isotopes of Radium (223,224,226,228Ra) are all enriched in groundwater when compared to seawater and display conservative properties in waters with brackish to marine salinities. For these reasons, the isotopes of Ra have been extensively used to quantify SGD in many coastal zones. Recently Ra has also been used to map SGD in lagoons (Beck et al. 2007, Ferrarin et al. 2008). Though Ra samples integrate SGD over a large area relative to point measurements with seepage meters, the distribution of Ra activity can be utilized to determine locations of high SGD, which can be difficult to find using conventional seepage meters. These radium maps can be utilized to understand the process and variability of SGD into coastal zones.

The relationship between spatially variant SGD and the dominant sediment type, given the same driving source, is significant. In coastal lagoons, the driver of SGD is often the local hydraulic head, which tends to be less variable than the sediment type. In many cases, higher resolution information is available for sediment composition than Ra activity, and, therefore by correlating sediment composition to Ra activity, we could potentially improve our understanding of the spatial distribution of Ra in the coastal lagoon based on the point measurements taken at the sampling sites.

SGD was quantified in the Venice Lagoon using a mass balance of Ra activity for each of the four isotopes. Ra samples were collected in 30 sites throughout the lagoon, and the activity of this sample was plotted. Various techniques were used to interpolate Ra activity throughout the lagoon and results were visually assessed. A clear pattern was seen with high radium for all four isotopes in both the southern and northern sections of the lagoon, regardless of the technique used. There were, however some clear instances of bias, depending on the interpolation technique used, as well as occasional problems with edge effects. Meanwhile, a concurrent study of sediment distribution was performed on more than 100 cores throughout the Venice Lagoon, and sediment was separated into grain size by percentage. This data was further amalgamated into 11 classes based on the USDA grain size diagram and plotted in the Venice Lagoon using ArcGIS. Grain size in-between known points were interpolated using, again, different techniques. Ra activity distribution was then compared with sediment size distribution. Each Ra point sample was compared with sediment samples within a given radius of the sample point. High resolution bathymetry was also utilized to determine grain size and known channels were considered natural borders. Sediment samples within the determined radius, yet in or on the other side of a channel were discounted due to the hydrodynamic barrier created by the channel properties.

The relationship between Ra activity and sediment size distribution was analyzed. In general we expected that sandy and sandy-silt size classes would correspond to high Ra activity however, in some cases the correlation was not perfect, specifically near the inlets, where large grain size sediment was found coincident with low Ra concentrations. Still, this is expected as water near the inlet is dominated by re-circulation with low activity Adriatic Sea water. With this new information and taken into account expected patterns near the inlets, we will most likely be able to recalculate the mass balance of Ra with more confidence in our final analysis.

With current technology and methods, SGD estimates are often given with 100% error bars and at worst within an order of magnitude. One of the problems is that the spatial analysis of SGD is limited. We suggest combining Ra analysis and sediment distribution in coastal lagoons to increase the confidence with which the scientific community can report SGD measurements.