Optical Brighteners as a Wastewater Plume Tracer in Estuarine Systems

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Abstract:

Wastewater inputs represent a significant source of reactive constituents such as nutrients, metals, and organic pollutants into aquatic systems. The ability to trace the input of reactive constituents from wastewater treatment facilities to receiving water bodies is essential. Optical brighteners (OBs) are organic compounds present in nearly all modern laundry detergents that are released into water bodies that receive wastewater effluent even after treatment through a water treatment facility. Optical brighteners represent a potential tracer for wastewater inputs in aquatic systems. In May 2012, discrete surface water samples were collected from the tidal-fresh Potomac River, Washington D.C. to measure the presence of OB's and the rare earth element, Gadolinium (Gd), a known wastewater tracer released into effluent stream through medical use. Samples were collected from sites radiating outwards from the outfall of the Blue Plains Advanced Water Pollution Control Plant (BPWPCP), one of the largest tertiary treatment plants in the world. Results show a correlation between OB concentration and distance from the water treatment facility but only a weak correlation with Gd. Gadolinium represents an effective tracer because of its conservative nature; its concentration will decrease only as a function of mixing. Optical Brighteners, however, represent a potential semi-conservative tracer. Optical brighteners are susceptible to photo-oxidation, indicating that they would best be used as a tracer in environments where photo-oxidation is less likely to occur. Further studies about the rates of photo-oxidation of OB's in aquatic systems are required before it can be validated as an effective wastewater tracer.

Study Area and Methods:

Figure 1. Google Earth view of the sampling area of the tidal-fresh Potomac River. The yellow dots denote the sample points for data collection on May 10, 2012. The BPWPCP is highlighted in the upper right hand corner.

Figure 1 shows the Potomac River study site. *In-situ* data on water column parameters were collected using a Hydrolab Quanta and surface water samples were collected for metals analysis (Rb, Gd) and OB analysis (**Fig. 2**). Metals were analyzed using High Resolution Inductively-Coupled Mass Spectrometry and OBs were analyzed using using a Turner Designs Ltd. Model 10-AU Fluorometer tuned and calibrated to detect optical brighteners (method modified from O'Connor (1996) and Hagedorn et al. (2002)) .

Figure 2. MIDN 1/C Baker and MIDN 1/C Kelly collecting surface samples on the Potomac River in November 2012. The data collected in November will be used to further evaluate the use of optical brighteners as a wastewater plume tracer. Similar measurements for optical brighteners were made on May 10, 2012.

Results:

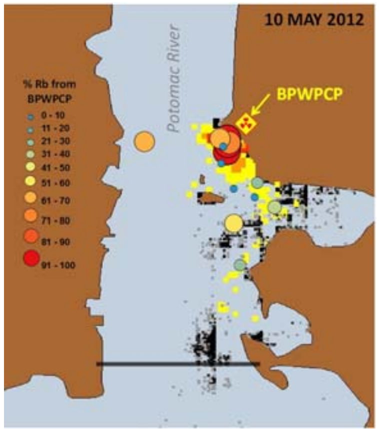

Figure 3. Results of measured % Rb from BPWPCP plotted against the output of a SHARC model run simulating and input of 50 kg of ^{137}Cs from BPWPCP to the Potomac River over 10 days, 01-10 MAY 2012 (Kelly, 2013). Red color denotes highest, orange denotes moderate, and yellow denotes lowest predicted ^{137}Cs aqueous activities. Black denotes highest and grey denotes lowest predicted ^{137}Cs sediment activities.

Figure 3 shows a comparison of a SHARC model output for ^{137}Cs released into the tidal-fresh Potomac River to field measurements of % Rb from BPWPCP in discrete surface water samples collected on May 10, 2012 (Kelly, 2013). The System for Hazard Assessment of Released Chemicals (SHARC) is a waterborne chemical modeling tool developed made by RPS ASA, Inc. for DTRA. Kelly (2013) used Rb as a proxy to show that SHARC does a good job in predicting the dispersion plume for ^{137}Cs. **Figure 4** shows a comparison of measured OB data to the same SHARC simulation. Field OB measurements map well to SHARC predictions closer to the BPWPCP outfall but not as well farther away from the source.

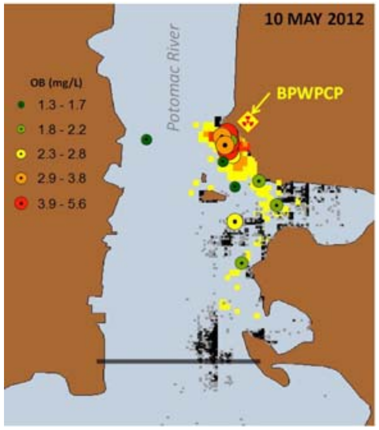

Figure 4. Results of measured OB concentrations from BPWPCP in the Potomac River plotted against the output of a SHARC ^{137}Cs simulation for May 10, 2012.

Discussion:

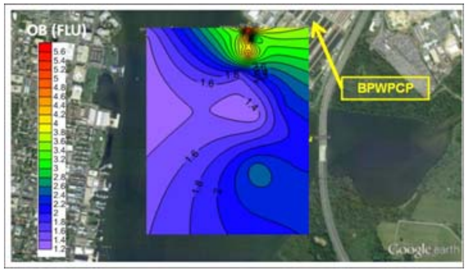

Figure 5. Gridded contour plot of OB data for May 10, 2012 created with Surfer 11.0 using an inverse distance squared interpolation scheme.

Figure 5 shows a gridded contour plot for the OB data collected on May 10, 2012 as the wastewater effluent leaves BPWPCP. The plot, as expected, shows the highest concentrations near the outfall and diminishing concentrations with distance into the river. The fact that OB's behave semi-conservatively accounts for the patches of both high and low concentrations observed. Studies by others have shown that OBs can be photo-oxidized in surface waters (Tavares et al., 2007). **Figure 6** shows the measured concentrations of OB's compared to those of an established wastewater tracer, Gd (Hagedorn et al., 2005). A linear relationship was not expected because Gd behaves more conservatively than OBs. Results do suggest a relationship between the two tracers in low turbidity waters where photo-oxidation plays less of an effect.

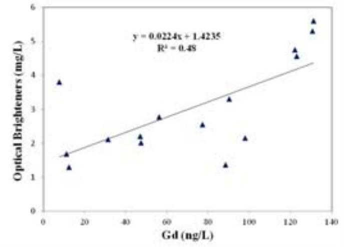

Figure 6. Comparison of Gd concentrations to OB concentrations measured in surface waters of the tidal-fresh Potomac River near the BPWPCP on May 10, 2012.

Conclusions:

- ***Results show that optical brighteners can potentially be used as a tracer for wastewater inputs into estuarine systems.***
- ***The utility of OBs as a wastewater tracer is limited by its semi-conservative behavior in surface waters (photo-oxidation).***
- ***Optical brighteners are relatively easy to measure in waters using fluorometry and present a potentially cheaper and more efficient manner to track a wastewater plume.***
- ***Further studies about the rates of photo-oxidation of OB's in aquatic systems are required before it can be validated as an effective wastewater tracer.***

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