Ways to Define Contamination and Find a Source: Beaverdam Creek as an Example

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Abstract:
It is very common to trace contamination through a "parameter-by-parameter" approach. This is especially useful in regulatory situations. However, it may not work as well in settings where there are many constituents of interest, and there are multiple potential sources. Multi-variate analytical techniques such as Stiff diagrams may work well in these cases. The advantages and disadvantages of these general approaches are discussed through a particular condition: tracing impacts from the Brookhaven landfill to Beaverdam Creek.

Introduction

Water resource contamination is an important environmental issue. There are often three separate problems in potential contamination settings. One is to define if a contamination problem exists, and, if so, to define the contamination sufficiently. Secondly, finding a cause for the contamination is often important. Finally, resolving the contamination, usually by selecting an appropriate remedial response, is often warranted.

However, there are many ways that these three key problems can be approached. Legal and institutional frameworks, or resource availability, can often define how the water quality issue is defined. The depiction of the contamination may either make identification of the source easy or hard to accomplish, with more or less certainty. And the combination of contamination definition and source identification often frames potential remedial approaches.

I would like to explore these issues, with a focus on defining contamination and establishing a probable source, through a case study of Beaverdam Creek. Beaverdam Creek is a small stream in south-central Suffolk County. Although its precise start of flow depends on groundwater elevations, it flows for approximately 1 mile as a narrow, fresh water stream, losing approximately 25 feet in elevation, from between Sunrise and Montauk Highways in the hamlet of Brookhaven to south of Beaverdam Road. At that point it becomes estuarine. The salt water Creek is defined by a broadening mouth that emerges into Great South Bay another mile south of Beaverdam Road (see Figure 1) (SCDHS, 2008). Beaverdam Creek, like all other Long Island surface waters, is almost entirely groundwater fed, although runoff can swell flows during and immediately after precipitation events (Wexler, 1988).

Figure 1. Beaverdam Creek Monitoring Program (from SCDHS, 2008)

The Suffolk County Department of Health Services Investigation

In 2003, a former salt marsh that had been used for dredge spoil disposal was remediated by a consortium that included Suffolk County. As part of the County involvement in the project, the Department of Health Services (SCDHS) took water samples in Beaverdam Creek to monitor potential effects. The results showed very high concentrations of ammonia in the Creek (at the ppm level, although ammonia is often undetectable at 10s of ppb in estuarine waters) (SCDHS, 2008).

These findings led SCDHS to conduct further monitoring to trace a source of contamination. SCDHS has its own analytical laboratory, the Public and Environmental Health Laboratory (PEHL). SCDHS normally samples estuarine water samples for a wide variety of nutrients (various nitrogen and phosphorus compounds) and pathogen indicators (such as coliform). SCDHS also analyzes many samples for volatile and semi-volatile compounds; the semi-volatile compound list is always being expanded, and the PEHL has pioneered methods to detect various pesticide degradates and has added many of "Personal Care Product and Pharmaceutical" (PCPPs) chemicals to its analyte list. The PEHL tends not to analyze salt water samples for metals, as high salt concentrations can foul the calibration of its machines. The analyte lists used by SCDHS reflect regulatory concerns (SCDHS oversees drinking water quality in Suffolk County on behalf of New York State) and the many environmental investigations conducted by SCDHS over the past several decades. Notable examples include tracking pesticides in groundwater (SCDHS, 2002), and monitoring water quality in the Peconic Estuary and the bays along the south shore. Independent observers of the PEHL often find its work to be exemplary, and it holds the highest certification level available: the USEPA Environmental Laboratory Approval Program (ELAP) (SCDHS, 2008).

SCDHS took further samples in the saline portion of the creek, and established stations in the freshwater portion, too. SCDHS found generally high concentrations of iron and manganese in the freshwater portion of the Creek, and elevated levels of coliform throughout the system. Salts such as chloride, sodium, and potassium were also found to be higher than anticipated in the freshwater part of the Creek. Dissolved oxygen concentrations were lower than expected. Some petroleum product constituents (MTBE, for instance) were detected, as were solvents (diethyl ether) and PCPPs (DEET, bisphenol A, ibuprofen) (SCDHS, 2008).

SCDHS noted an illegal discharge from a small office building to the creek, found houseboats in the estuarine portion discharging sanitary wastes directly to the Creek, found some stormwater outfalls from roads discharging into the fresh water creek, and observed that the medium-to-light density housing in the area used on-site sanitary systems for septic wastes, and that many of these were probably in close proximity to the high water table in this coastal setting. All of these elements could be contributors to the contamination phenomena measured by the County (SCDHS, 2008).

However, some of the contaminants were found even at the northernmost sampling point, which appeared to be too far north for any sanitary system or runoff inputs to be important contributors to the contamination. Two constituents which clearly exceeded water quality standards on a consistent basis and which increased in effect upstream were iron and ammonia. Some PCPPs and solvents were also found in the upstream samples (SCDHS, 2008).

Discussions with the Town of Brookhaven and its experts revealed that the Town's landfill could be a source of contaminants to the Creek (see below). A literature search and analysis of the patterns of contamination determined that it was possible for the landfill to be the source, and unlikely that other, potential sources could account for all of the identified phenomena (SCDHS, 2008).

Town of Brookhaven Investigations

Cell 1 of the Town landfill was one of the first artificially lined landfills in the US. However, containment failed, and the Town brought in the US Geological Survey (USGS) and a local academic (John Black, Suffolk County Community College) to investigate. The USGS installed a large network of groundwater wells, and sampled Beaverdam Creek, an obvious aquifer discharge point downgradient of the landfill. USGS took several rounds of samples to characterize various aspects of the plume, and created a model of the plume (Wexler, 1988). Black established an ongoing monitoring program. Both USGS and Black used Stiff diagrams to characterize the plume, and Black explicitly linked a particular diagram shape from leachate samples to groundwater samples (Black and Dellaria, 1992). Stiff diagrams are a 9-parameter depiction of anions and cations (Figure 2).

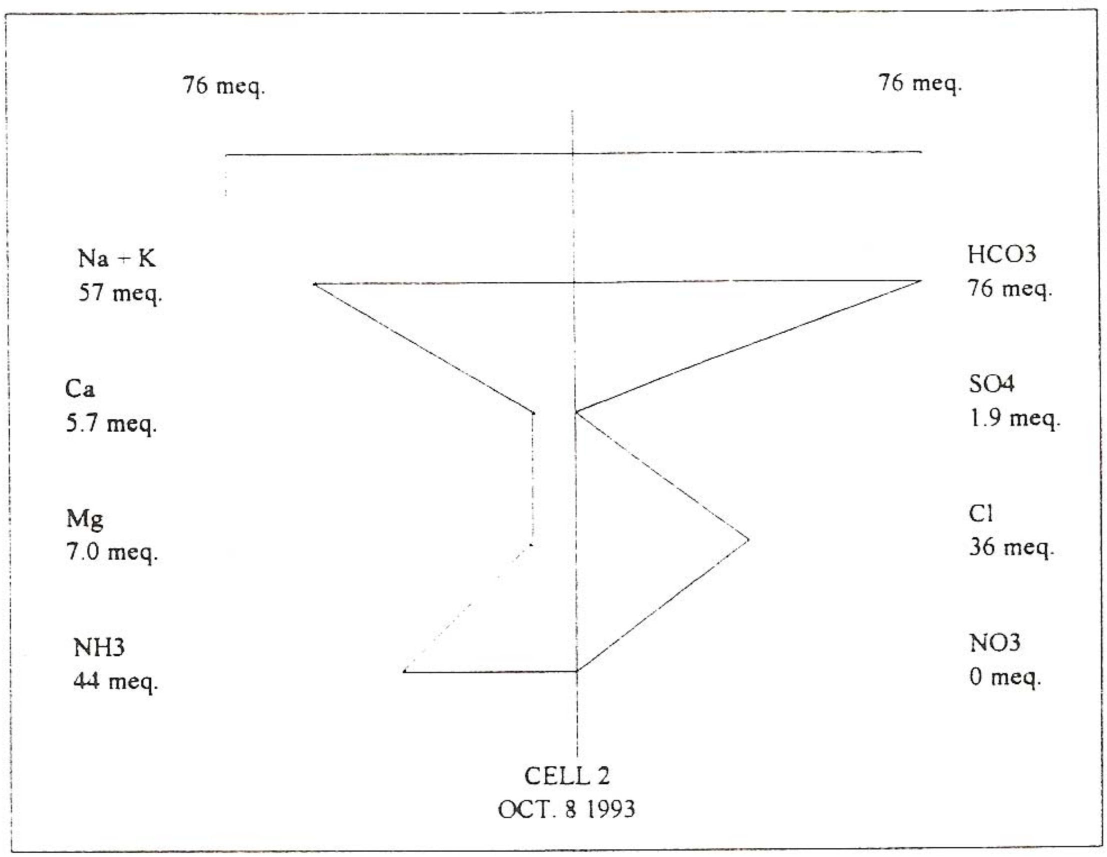

Figure 2. Stiff diagram example

I became involved in the monitoring program in 1992. Black and I traced the signature diagram shape to Beaverdam Creek samples taken in the summer of 1992, and the Town's report for 1992 spoke of "leachate contamination" in the upper reaches of the Creek (Tonjes and Black, 1993). Subsequent reports that I prepared, only one of which was intended for general public dissemination, also reported continuing contamination of the Creek, and exceedances of "drinking water" standards. Beginning about 2000, I expanded the analysis to include comparisons to appropriate Class C surface water quality standards (see Cashin Associates, 2002, for instance). Dvirka and Bartilucci, CE, began writing monitoring reports for the Town in 2005. D&B reports noted that there were multiple potential sources for all of the constituents measured above standards, and so it was not necessarily certain the landfill plume was the cause of contaminants in the Creek (Dvirka and Bartilucci, 2006).

The Town sampled for parameters listed in the New York State landfill regulations. These included many inorganic constituents, although not as many nutrient compounds as sampled for by Suffolk County. The Town's list of solvents was longer than the County's, but did not include all parameters measured for by the County. The New York State semi-volatile list, although long, focused on compounds associated with industrial operations, and did not include most PCPPs and modern pesticides on the County list. The Town's laboratory also has ELAP certification, although some reports have found that its performance can be criticized (SCDHS, 2008; Cashin Associates, 2002).

Comparing Approaches

Both SCDHS and I identify the landfill as the source of contamination in the Creek, but our approaches differ. I think some of the differences are important.

The SCDHS identification is driven by "weight of evidence." All of the individual constituents have multiple, local sources. Chlorides come from road salt and can be elevated due to salt spray or other inputs from the nearby estuary. The PCPPs are most commonly associated with human septic wastes, although SCDHS found references linking them to leachate contamination as well. The same is true for some of the solvent-linked compounds (SCDHS, 2008). Ammonia is also a common septic release, and high groundwater concentrations can result when there is little distance between the water table and the septic systems, as may be the case in Brookhaven hamlet. Iron is often made soluble and is found at higher concentrations near wetlands on Long Island (iron was mined from surface waters on the Peconic and Forge Rivers, for instance) (Cashin Associates, 2004). The contamination patterns for MTBE and coliform clearly linked them to non-landfill sources (SCDHS, 2008).

Ammonia concentrations in the fresh water Creek declined downstream, indicating an upstream source; but they also spiked in the saltwater section. SCDHS thought it addressed a potential reason for this contaminant pattern by ensuring that moored houseboats no longer discharged to the Creek, but another round of samples after this mitigation found the same pattern. This suggests another source of ammonia exists in the downstream portion of the Creek.

The PCPPs were not detected regularly, and detections did not necessarily correlate with concentrations of other constituents believed to be from the landfill (such as iron and ammonia). DEET is an especial concern; although the County notes it is rarely measured in estuarine samples, some detection patterns of this compound seem to point to sampler contamination of samples (Cashin Associates, 2008). There are growing reports that bisphenol A results nationwide include a great many false positives (it is a common plasticizer in laboratory equipment, and may be leaching from bottle caps into sample bottles) (B. Brownawell, Stony Brook U., personal communication, 2009). The SCDHS analysis dos not account well for detections of lower concentrations of contaminants at the northernmost sampling point on Beaverdam Creek than the two sampling points immediately downstream.

I believe the Stiff diagram analysis addresses many of these issues. The identification of similar samples enables a coherent, comprehensive picture of contamination to be developed, and provides a framework to explain those results that do not fit the general pattern. The relative degree of contamination in stations along the creek can be linked to the discharge of groundwater to the Creek. The uppermost aquifer is less contaminated, so the northernmost station, where streamflow is low, receives less contaminated groundwater than stations immediately south that receive groundwater discharges from deeper in the aquifer (as discussed in Tonjes and Black, 1994). Iron concentration variations are explicable because, unlike the soluble salts measured in the Stiff diagrams, iron is redox-sensitive, and so may be enhanced or reduced by changes in the oxidation potential of the aquifer or stream (Tonjes et al., 1995). Town sampling data has found it difficult to correlate organic compound concentrations to other measures of contamination; mostly it has been assumed this is because of laboratory performance variability. However, detection of characteristic compounds also found in groundwater near the landfill thus serves as confirmation of the plume impacts. SCDHS did not ask to share samples or to independently sample groundwater from near the landfill, and so cannot link organic contaminants not sampled for by the Town to the plume directly.

However, Stiff diagrams cannot be used in marine waters, as marine waters all share a similar Stiff diagram shape. My focus on Stiff diagrams alerted me to the presence of the landfill plume constituents in the Creek, but this focus led me to pay less attention to potential ecological effects that might have been more apparent with a parameter-by-parameter approach.

Conclusion

The better approach is to fuse the two ways of looking at and understanding contamination. The Stiff diagram is a strong and conclusive tracer of the leachate plume. The wider range of constituents monitored for by SCDHS extends the understanding of potential effects associated with the plume, especially if those parameters were to be linked to either leachate or “close-to-the-landfill” sampling points. The SCDHS approach also supports tracing of impacts into marine waters. Greater awareness of single parameters also can help keep attention on potential effects, rather than just tracking the phenomenon.

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