Effects of Total Dissolved Solids in Streams of Southwestern Virginia

Stephen Schoenholtz, Director, Virginia Water Resources Research Center, Virginia Tech

David Soucek, Ecotoxicologist, Illinois Natural History Survey

Carl Zipper, Associate Professor, Crop and Soil Environmental Sciences, Virginia Tech

Anthony Timpano, Graduate Student, Environmental Science and Engineering, Virginia Tech

Background and Approach

Total dissolved solids (TDS) are the inorganic salts, organic matter, and other dissolved materials in water. Elevated TDS can be toxic to freshwater animals by causing osmotic stress and affecting the osmoregulatory capability of the organism (McCulloch *et al.* 1993). Several prior studies have concluded that the toxicity of TDS is a function of the solution's ionic composition as well as the TDS concentration (Goetsch and Palmer 1997, Mount *et al.* 1997; Clements 2002; Goodfellow 2000; SETAC 2004; Kennedy *et al.* 2005) and organism sensitivity.

Under the Clean Water Act, water quality criteria are components of water quality standards. As defined by the Code of Federal Regulations, criteria are "… elements of State water quality standards, expressed as constituent concentrations, levels, or narrative statements, representing a quality of water that supports a particular use. When criteria are met, water quality will generally protect the designated use" [40 CFR 131.3(b)]. All Virginia waters are required to support a designated use defined by Virginia Department of Environmental Quality (DEQ) as "the propagation and growth of a balanced, indigenous population of aquatic life" (Virginia DEQ, 2007).

In 2006, Virginia DEQ initiated an evaluation of the potential to establish water quality standards for TDS as a response to total maximum daily load (TMDL) studies of streams draining watersheds affected by mining in southwestern Virginia (Maptech Inc 2004, 2005a, 2005b). Based on this evaluation, DEQ decided to proceed with an evaluation of the potential to establish a TDS water quality criterion.

A review of scientific literature and an analysis of Virginia DEQ water monitoring data concluded that neither of these two information sources provides an adequate basis for establishing water quality standards for TDS in Virginia (Zipper and Berenzweig 2007). The report recommended that, should Virginia DEQ choose to proceed with development of TDS criteria despite the lack of an adequate scientific knowledge base, such development should be based on studies of aquatic communities in natural streams of varying TDS levels where non-TDS stressors have minimal influence. The report suggested that component-ion effects should be considered in the development of such criteria.

Furthermore, Zipper and Berenzweig (2007) recommended that the benthic macroinvertebrate community should be considered as the target community in TDS criteria development, given that Virginia DEQ currently uses the benthic macroinvertebrate community as a bioindicator for Clean Water Act enforcement, and considering the wording of Virginia water-quality standards, which protect "the propagation and growth of a *balanced, indigenous population* of aquatic life" [italicized emphasis added], and the trophic role of benthic macroinvertebrates in aquatic systems. Such an approach is consistent with discussion regarding

potential TDS criteria among US Environmental Protection Agency, Maptech, Virginia DEQ, Virginia Department of Mines, Minerals and Energy, and Virginia Tech personnel in late 2006.

Virginia DEQ currently uses a multimetric benthic macroinvertebrate community index, the Stream Condition Index (SCI), as its basis for water-quality assessment of benthic macroinvertebrate data (Burton and Gerritsen 2003; Virginia DEQ 2006). The approach proposed here will utilize the Virginia SCI (VSCI) to evaluate TDS and/or component ion effects on benthic macroinvertebrate communities. Research goals will be (1) to develop a database comprised of TDS-SCI relationships, and associated attributes such as habitat metrics, for freshwater streams that can support a recommended TDS criterion; and (2) to define a TDS and/or component ion concentration level that may be considered by DEQ for designation as a water quality criterion.

Research Methods

1. Identify freshwater stream research sites that have elevated (i.e., above reference or background) TDS concentrations but appear to be otherwise relatively unaffected by non-TDS stressor effects.

Research sites will be identified in consultation with VDMME, Virginia DEQ, and other cooperators. Virginia DMME databases will be accessed to identify active mining sites and completed mining sites, and streams draining those sites where TDS concentrations are elevated relative to background. GIS analyses, aerial photography and/or satellite imagery, and DEQ/DMME point-source discharge databases will be used in an effort to identify those high-TDS sites where non-TDS stressors do not appear to be present. We will attempt to locate 40 to 50 non-reference (elevated TDS) research sites, in total.

2. Identify 10 to 20 freshwater stream research sites that can serve as unstressed reference locations.

These research sites will be used as reference sites for comparison with TDS-affected sites. Reference streams will be selected based on similar geology and topography to the applicable non-reference streams in an effort to isolate TDS and the benthic population as the variables.

3. At each research site, sample benthic macroinvertebrates.

Sampling should be carried out during the spring and fall benthic macroinvertebrate sampling seasons under baseflow conditions (verified by DEQ/DMME flow data if available), avoiding time periods immediately following potentially scouring stormflow events, using a qualitative protocol similar to that described in Barbour et al (1999). Benthic macroinvertebrate samples will be identified to the genus level with the exception of midges, which will be identified to the tribe level

4. Characterize non-TDS stressor and other benthic macroinvertebrate community influences at all research sites by sampling habitat elements and water quality.

A complete physical habitat assessment will be conducted at each sampling site according to protocols described in Barbour et al. (1999). Parameters characteristic of low-gradient streams like channel sinuosity, pool variability, and pool substrate characterization will be excluded.

Water quality at each site will be characterized at the time of spring and fall benthic macroinvertebrate sampling for field parameters (pH, conductivity, temperature, dissolved oxygen) using a portable multi-probe sampler, major ions (Ca, Mg, K, Na, Cl, Sulfate), total dissolved solids, and metals (to include Cu, Zn, Mn, Se, Al, Fe). Samples that will be used in metals analyses will be field filtered. Inductively coupled plasma emission spectrometry (ICP) will be used to measure dissolved Ca, Mg, K, Cu, Zn, Mn, Se, Al, Fe (APHA 1998). Ion chromatography (IC) will be used to measure CO_3^{2-}/HCO_3^-, Cl and sulfate; TDS will be measured via filtration followed by drying at 180°C; and total alkalinity will be measured via titration with standard acid.

5. Analyze data to determine a potential TDS criterion.

The VSCI will be the biotic indicator used to define an impairment threshold for use in data analysis. The impairment threshold used by Virginia DEQ (VSCI = 60) will be used in this study.

The influences of TDS and component ions on the biotic indicator metric scores will be determined through a multiple regression approach. Component ion concentrations will be expressed on relative scales by summing all major cations (K^+, Ca^{++}, Mg^{++}, Na^+) and anions (CO_3^{2-}, HCO_3^-, SO_4^{2-}, Cl^-) separately and expressing each component-ion concentration both as a percentage of the cation/anion concentration total and as a concentration. In this multiple regression procedure, the VSCI will be the dependent variable and (relative-) concentrations of component ions will be the independent variables. In this procedure, potential multicollinearity effects of component ion concentrations and TDS will be controlled. Discriminant analysis will be employed to determine whether or not any of the measured habitat elements or other site characteristics is exerting an influence on SCI scores; if so, these will also be included as independent variables in the multiple regression procedure. A stepwise variable selection procedure will be employed to identify those variables exerting influence on the SCI scores at the research sites, and an SCI-prediction equation will be developed. Potential criteria will be defined using the SCI prediction equation to define TDS and/or component ion concentrations (or concentration relationships) that are adequate to maintain SCI scores at non-impaired levels. In addition, data will be analyzed to define a TDS/component ion levels that assure presence of all major functional groups and families that are normally present as significant community components in reference streams. Potential TDS criteria will be defined at levels where the data indicate adequacy to support “a balanced, indigenous population of aquatic life.”

Progress to Date

The study is being conducted with financial support that combines resources from Virginia DEQ, Virginia DMME, and Powell River Project (PRP).

Full-time activities were initiated in late July, 2008, with plans to conclude activities in December 2010. Activities to date include meeting with Virginia DEQ and Virginia DMME personnel to assure coordination, initiation of efforts to locate suitable sampling sites, and initiation of field sampling trials for the purpose of refining and standardizing sampling procedures. We intend to initiate sampling in the fall of 2008; and to continue sampling site location efforts through the winter of 2008-09 so as to have the full suite of field sampling sites identified by spring of 2009.

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