Demonstrating BMP Effectiveness with Microbial Source Tracking and Host Fecal Score

Mauricio Larenas
Source Molecular Corporation, FL
mlarenas@sourcemolecular.com

ABSTRACT

Stakeholders in the Animas and San Juan watersheds routinely measure, among others, E. coli concentrations in the rivers. Microbial source tracking (MST) has been used to identify sources of contamination. MST markers, being specific to their targeted fecal sources, can specifically demonstrate if a particular source has been mitigated by the BMP even if FIB levels show little change. Additionally, a site human fecal score (HFS) has been developed by a team of researchers, from the U.S. Environmental Protection Agency, Southern California Coastal Water Research Project (SCCWRP), and Stanford University, to objectively assess the extent of human fecal contamination at a site using a standardized mathematically defined approach. The HFS gives a simple and intuitive way to assess and communicate BMP effectiveness by providing a score before and after BMP implementation.

INTRODUCTION

The most common pollutants and water quality problems reported in New Mexico include bacteria, nutrients, sediment, toxic metals and PCBs. The state is tasked under the Clean Water Act (CWA) to monitor all of its waterways, present that information to the public and restore polluted waters. The San Juan Soil & Water Conservation District (SWCD) noted that in recent years, the Animas and San Juan rivers have exceeded recommended limits of bacteria and nutrients in numerous locations.

Stakeholders in the Animas and San Juan watersheds routinely measure, among others, E. coli concentrations in the rivers. E. coli is one of the three most common causes of river and stream water quality impairments based on stream mileage in New Mexico.

Water quality issues often make headlines, increasing pressure on watershed managers to fix the problem. In addressing fecal contamination, watershed managers have traditionally turned to fecal indicator bacteria (FIB) in monitoring the presence of fecal matter in environmental waters. The chain of inference in water quality monitoring generally assumes that FIB in the water means there is waste. Waste is assumed to be human waste, which is understood to have pathogens. Pathogens are the organisms that can cause diseases. But the chain is broken when the assumptions aren't correct.

FIB are generally not pathogens themselves. FIB can come from a lot of sources - humans, animals, plants, soil, and biofilm. The public health risk changes from the different sources. This makes FIB an unreliable surrogate for pathogens and an ineffective tool to assess fecal contamination in areas where multiple sources exist.

MICROBIAL SOURCE TRACKING

The San Juan SWCD and its partners, including the San Juan Watershed Group, have been working to identify the sources of pollution in local rivers. Watershed managers recognize that it is difficult to implement mitigation measures without knowing exactly where the bacteria came from. One of the technologies used to identify bacteria sources is microbial source tracking (MST).

MST is a set of methods used to identify the bacteria source. The technology analyzes gut bacteria and looks for genetic markers that are unique to specific hosts. The unique microbial DNA sequences are used as markers in PCR assays for the detection of fecal contamination in water for that particular source.

Genetic testing has been used in other industries such as forensics and food. It's been dubbed as the new gold standard in forensic science and used by the Centers for Disease Control and Prevention in finding the source of E. coli outbreaks.

Genetic technology provides answers to questions such as where is the pollution coming from, who is responsible, and how to evaluate effectiveness of best management practices (BMPs). BMPs are used to target the identified sources of contamination for mitigation. By using MST markers, watershed managers can specifically demonstrate if their BMPs have been effective in mitigating a particular source regardless of the FIB levels.

MST DEVELOPMENT & APPLICATIONS

There is a tremendous amount of precedent in the utilization of MST technology. MST projects are being conducted all over the United States. It has achieved national validation and recognized in projects such as the State of California Source Identification Pilot Project (SIPP) Method Evaluation Study, where they developed a source identification manual that includes MST. An MST laboratory in Florida has also been accredited by the International Organization for Standardization (ISO), in further recognition of the testing methods. Moreover, an objective interpretation of MST results have also been developed by a team of researchers to remove biases found in best professional judgment (BPJ).

MST is also being applied at each stage in the Clean Water Act. The primary objective of the Clean Water Act is to restore and maintain the integrity of the nation's waters. The water quality-based approach of the CWA includes assessing the waters, listing impaired and threatened waters, and developing the Total Maximum Daily Load (TMDL). DNA analysis of water samples is also being accepted in stormwater permitting.

The Georgia Department of Natural Resources, for example, indicated in its Authorization to Discharge Under the National Pollutant Discharge Elimination System (NPDES) Storm Water Discharges Associated with Industrial Activity that scientific testing, such as DNA analysis, may be used to document that bacteriological constituents found in stormwater discharges from the facility are not present as a result of industrial activity at the site or are below the impaired waters benchmark for fecal coliform.

Planning an MST project involves careful selection of sampling sites, sampling events and tests. Sampling sites must be selected based on fecal bacteria hotspots and must represent the watershed's spatial variability. Samples must be collected near physical sources. Sampling events should occur during wet and dry weather and should take into account seasonal changes. There must be a significant number of sampling events to represent temporal variability. In choosing the tests, focus should be given on anthropogenic sources such as human, dog, and agriculture. If wildlife is the most likely source, then test for birds and deer.

MST CASE STUDIES

Martin County, FL

MST is useful in site prioritization as demonstrated by a project conducted by Martin County in Florida. The County identified high levels of fecal contamination at an estuary that had a septic system. They had an assessment and determined that they need to switch the septic system into a sewer system. They hired a consultant who calculated that the system change was going to cost the County at least $138 million. The County did not have the money on hand do this so they developed a 100-year plan to implement the change. Their problem was how to begin in a way

that would have a positive impact on the water quality. The County determined that they needed to rank the sites in order to know which sites to prioritize. They used MST markers to do the site ranking. Out of 25 geographic sites, the County was able to identify two principal areas where they would have the biggest impact on the human waste in the estuary. This could only be achieved with MST and not legacy technologies.

Boston, MA

The first ever effectiveness assessment of an MS4 Illicit Discharge Detection and Elimination (IDDE) program used DNA markers. It was for a study that won an award from the National Association of Clean Water Agencies (NACWA). The MST study is entitled "Utilizing DNA Markers for Identification of Human and Non-Human Fecal Sources in Urban Stormwater." GeoSyntec Consultants designed and led the MST study for the Boston Water and Sewer Commission (BWSC). BWSC maintains the City of Boston's water and sewer services and continues to implement one of New England's most rigorous IDDE programs throughout their Municipal Separate Storm Sewer System (MS4). As an additional proactive measure, BWSC retained GeoSyntec to determine whether and where bacteria in their MS4 outfalls and interconnections are due to human versus non-human sources and to evaluate ongoing IDDE program efficiency. GeoSyntec developed a hypothesis-driven study that assesses bacteria and nutrient sources to and within BWSC's MS4. GeoSyntec also assessed the spatial/temporal patterns of these pollutants, and the reliability of conventional and EPA-recommended IDDE indicators. The study incorporated the latest and most proven analytical tools. This includes droplet digital quantitative PCR for human and non-human DNA markers.

Santa Barbara, CA

In California, MST technology helped Santa Barbara not only to identify pollution sources at their beaches but also to measure the impact of their best management practices (BMP). Under a Clean Beaches Initiative grant, Santa Barbara used MST to identify what was causing the high levels of fecal pollution in their beaches. They found out that one of the major contributors were dogs. One of the BMPs they carried out was an outreach program where they went door to door and encouraged dog owners to pick up after their dogs. After implementing this BMP, Santa Barbara conducted further MST analysis to determine if their outreach program was effective in reducing the dog fecal bacteria in the water.

HUMAN FECAL SCORE

BMP effectiveness can also be demonstrated using a site human fecal score (HFS). The HFS has been developed by a team of researchers, from the U.S. Environmental Protection Agency, Southern California Coastal Water Research Project (SCCWRP), and Stanford University, to objectively assess the extent of human fecal contamination at a site using a standardized mathematically defined approach.

MST data is usually interpreted using best professional judgment (BPJ) but a study showed that there is a high level of inconsistency among experts. For that reason, researchers sought to remove bias in MST data interpretation and reduce it into a single number that statistically integrates all human fecal marker data from all samples at a given site. All data means those that are quantifiable, detected but not quantifiable, and non-detect because even non-detects contain valuable information.

The HFS gives a simple and intuitive way to assess and communicate BMP effectiveness by providing a score before and after BMP implementation. This approach can also be applied to other fecal host sources, for example, a cow fecal score if a cow fecal MST marker is used in place of the human fecal MST marker. The use of these advanced technologies therefore can provide effective evaluation of BMP performance, and inform selection and implementation of BMP to obtain highest benefit of protecting public health with lowest cost of BMP implementation.

REFERENCES

Cao, Y., Hagedorn,C., Shanks, O.C., Wang, D., Ervin, J., Griffith, J.F., Layton, B.A., McGee, C.D., Riedel, T.E., Weisberg, S.B., 2014, Towards establishing a human fecal contamination index in microbial source tracking: International Journal of Environmental Science and Engineering Research 4(3), p. 46-58.

Cao, Y., Sivaganesan, M., Kelty, C.A., Wang, D., Boehm, A.B., Griffith, J.F., Weisberg, S.B. and Shanks, O.C., 2018, A human fecal contamination score for ranking recreational sites using the HF183/BacR287 quantitative real-time PCR method: Water Research, v. 128, p. 148-156.

Georgia Department of Natural Resources, 2017, Authorization to Discharge Under the National Pollutant Discharge Elimination System (NPDES) Storm Water Discharges Associated with Industrial Activity, Permit No. GAR050000, Appendix C.2.4.2, p. 152.

Izaak Walton League of America, 2016, Clean Water: Your Right to Know, p. 91-93.

Lemon, S., Annual Report New Mexico Environment Department Surface Water Quality Bureau Watershed Protection Section, 2017

May, M., Animas and San Juan Concurrent Nutrient & Bacteria Monitoring Project (unpubl. Final Report prepared for IGA No. 14-667-2000-0025, 2016)