

Report for 2005MA52B: Sources of E. coli during Wet-Weather Events

Publications

- There are no reported publications resulting from this project.

Report Follows

Sources of *E. coli* during Wet-Weather Events

Sarah M. Dorner, Jianyong Wu
Department of Public Health, University of Massachusetts Amherst
June 2006

1. Introduction: A Critical Regional Water Problem

Following the beginnings of modern water treatment more than a century ago, waterborne diseases such as cholera and typhoid fever were greatly reduced in the developed world. Then in 1993, an outbreak in Milwaukee, Wisconsin involving more than 400,000 cases of gastroenteritis caused by the protozoan parasite *Cryptosporidium parvum* was linked to the city's drinking water source (Mackenzie et al., 1994). Furthermore, in 2000, Walkerton, Ontario experienced a waterborne disease outbreak caused by the bacteria *E. coli* O157:H7 and *Campylobacter jejuni* resulting more than 2000 cases of gastroenteritis and seven deaths (O'Connor, 2002). Both of these outbreaks followed periods of heavy rainfall, as have others (Hrudey et al., 2002; Hunter, 2003).

The first recommendation of the report of Part 2 of the Walkerton Inquiry that examined the Walkerton waterborne disease outbreak was related to source water protection. It recommended that all drinking water sources be protected through the development of watershed-based source water protection plans (O'Connor, 2002). Therefore, it is now widely accepted that source water protection is an element of ensuring the safety of our drinking water supplies. However, what is less well understood is how to determine if a water source is adequately protected, particularly as greater urbanization and agricultural intensification are placing increasing pressures on our water resources.

Many waterborne pathogens may also be transmitted through food or direct contact with infected individuals or animals, but once present in a given population, pathogens can enter watercourses via a variety of sources. Pathogens sources in a watershed can include wildlife, agriculture, treated wastewater discharges, combined sewer overflows, and storm water runoff. Other specific examples of sources of pathogens are manure spread on land, the unintentional leakage from sewers and septic systems, or manure storage facilities.

In watersheds with a high population density and significant agricultural production, determining the survival times and pathways of pathogens in the environment once released helps to establish the frequency of high levels of pathogens arriving at a water treatment plant that could overwhelm the system. It is essential that treatment plants be capable of handling peak concentrations of pathogens. Information regarding baseline levels and peak concentrations of major pathogens of concern should be available to ensure robust treatment plant design. However, this information is often unavailable, in part because of the cost involved in collecting the data and uncertainty in the methods used for enumeration of pathogens such as *Cryptosporidium* spp. Furthermore, few modeling studies have been performed that could offer additional insight into probable pathogen concentrations, partially a result of a lack of data. Information regarding the sources of pathogens is needed for evaluating the impact of management practices aimed at reducing pathogen loads. Deeper knowledge of the relative importance of the sources will permit strategic targeting of remedial measures for pathogen reduction.

Stream sediments are potentially important reservoirs of pathogenic microorganisms. During hydrologic events, pathogens may be resuspended from the sediments to the overlying water column. The relative importance of land-based versus sediment based sources of pathogens and indicators is important for the development of source water protection plans, as well as modeling the fate and transport of pathogens at a watershed-scale.

Through the use of both monitoring and modeling, an overall goal of this study is to assess the temporal and spatial variability of *E. coli* in stream sediments and in the water column. The information gained from this study will assist in the identification of primary contributing potential sources of pathogens in such a watershed and will have the potential to positively influence the implementation of management practices with regard to their efficiency and effectiveness.

The specific objectives of this investigation were to:

- determine *E. coli* densities in water and sediment samples, with particular emphasis on storm water samples,
- estimate the absolute and relative numbers of *E. coli* from land based and sediment sources,
- identify the environmental conditions such as temperature, solar radiation, hydrologic conditions (i.e. antecedent moisture content, streamflow, precipitation) that contribute to peak occurrences of *E. coli*,
- increase our fundamental understanding of the mechanistic behavior of microbial fate and transport, and
- develop a set of recommendations for assessing source waters for pathogenic contamination.

2. Materials and Methods

Study site

The Blackstone River originates in the Worcester hills in central Massachusetts, and flows southeasterly into Rhode Island, discharging eventually into Narragansett Bay. Like many major waterways in the New England region, the water and sediment quality of the Blackstone River watershed was historically impaired by intense industrial development and urbanization (Figure 1), resulting in the discharge of untreated industrial and domestic wastes. The presence of numerous dams along the river, with at one point as many as one dam for every one mile of river, significantly impacted the fate and transport of these historical contaminants. The river continues to be plagued today by contaminated sediments trapped upstream of these impoundments.

Significant improvements in the overall water quality of the Blackstone River have been made in the past 30 years as a result of the Clean Water Act and the other pollution reduction initiatives. Despite this, the entire mainstem Blackstone River in the Massachusetts portion of the basin is impaired (defined as partial support and non-support) with respect to aquatic life and primary/secondary use attainment (MADEP 2002 303(d) List). Additionally, segments of the Blackstone River in Rhode Island fail to meet that state's water quality standards. According to the 2002 303(d) List of Impaired Waters prepared by the Rhode Island Department of Environmental Management (RIDEM), causes of impairment include biodiversity, excess algal growth, lead and copper, low dissolved oxygen concentrations, and pathogens.

The monitoring consisted of wet weather event sampling for *E. coli*. Events to be sampled were selected based on meteorological forecasts. A minimum of one water sample (with duplicate) and one sediment sample (with duplicate) were collected per sample location. The monitoring scheme was designed to complement past- and on-going data collection efforts by other organizations working in the watershed.

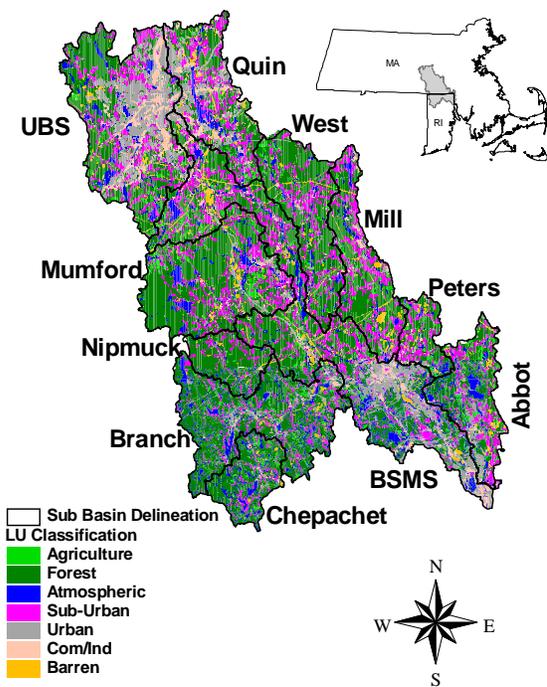


Figure 1. Land Use in the Blackstone River Watershed.

Site Descriptions:

BS1: BS1 is at the USGS Millbury Gauge. It is located downstream of the effluent discharge of the Upper Blackstone Water Pollution Abatement District.

BS4: BS4 is located on the Blackstone River upstream of the Upper Blackstone Water Pollution Abatement District.

MR2: MR2 is located on the Middle River, a tributary of the Blackstone River.

Method for the Enumeration of *E. coli*

Sample collection: During wet weather, surface water and sediment samples were collected 6 times in 3 sites from the Blackstone River. At times, sediment samples were not possible to collect due to excessive flooding. Water samples near the sediments were also collected. Water samples were taken in 500ml bottles and sediment samples with some water were taken by a long glass pipet in small bottles. All the bottles were sterilized. The samples were kept in an ice cooler and sent back immediately for analysis within 4 hours.

Enumeration of *E. coli*: *E. coli* was monitored by Colilert method (IDEXX Company, USA). Water samples were diluted with PBS buffer by 10 or 100 times. Then, 100 mL of diluted liquid was placed into vessels and reagents were added and mixed. The mixtures were poured into Quanti-Tray[®]/2000, sealed in a Quanti-Tray[®] Sealer and placed in incubator for 24 hours at 35 ± 0.2 °C. The yellow wells in the trays indicated the presence of total coliforms, and the yellow wells with fluorescence indicated the presence of *E. coli*. Total coliforms and *E. coli* were enumerated using an IDEXX Quanti-Tray[®]/2000 MPN table. For sediment samples, sediments were resuspended within the existing water matrix and hand shaken for several minutes. Then 10ml of liquid was placed into vessels and diluted either 10 or 100 times. The ensuing steps were the same as for water sample analysis described above.

Statistical analysis

Statistical analysis was carried out using SPSS 12.0 software. The Pearson correlation coefficients were calculated for *E. coli* and total coliforms in water and sediments

3. Results and Discussion

E. coli in water samples

At site BS1, *E. coli* concentrations gradually increased from May 9 to May 14, and then decreased to baseline levels on May 17. At site BS4, *E. coli* concentrations fluctuated with the peak concentration occurring on May 12. A similar trend was observed at site MR2 (Table 1), possibly reflecting a different response following heavy precipitation.

Table 1. *E. coli* densities in water samples

Date	BS1 (MPN/100mL)			BS4 (MPN/100mL)			MR2 (MPN/100mL)		
	Min	Max	Geometric mean	Min	Max	Geometric Mean	Min	max	Geometric mean
May 9	185	310	243	1210	1455	1305	520	630	554
May 10	200	410	288	200	520	340	100	630	204
May 12	200	520	322	2000	4100	2576	1870	2000	1946
May 13	520	987	692	730	1076	869	602	1100	812
May 14	960	1710	1401	934	1460	1243	1200	1989	1472
May 17	100	228	176	450	980	655	175	410	252

Table2. *E. coli* densities in sediment samples (per gram dry weight)

Date	BS1 (MPN/g)			BS4 (MPN/g)			MR2 (MPN/g)		
	Min	max	Geometric mean	Min	Max	Geometric Mean	Min	max	Geometric mean
May 9	NA	NA	NA	23	82	47	10	29	19
May 10	2	11	5	6	17	10	7	14	10
May 12	8	8	8	46	57	52	39	227	83
May 13	35	84	52	11	123	40	71	169	106
May 14	NA	NA	NA*	NA	NA	NA*	202	476	277
May 17	5	58	14	13	49	25	14	24	18

*NA – Not available due to excessive flooding

E. coli in sediments

At site BS1, *E. coli* concentrations were highest on May 13 and decreased to baseline concentrations on May 17. At site BS4, the concentration of *E. coli* varied slightly over the course of the event. At MR2, *E. coli* concentration increased sharply from May 10 to May 14, and decreased to normal on May 17 (Table 2).

Statistical analysis

Pearson correlation analysis illustrated that there existed significant correlations between *E. coli* and total coliforms in water ($r = 0.397$, $p = 0.0020$) and sediments ($r = 0.728$). In addition, *E. coli* concentrations in water were significantly correlated with sediment concentrations ($r = 0.318$, $p = 0.018$). These relationships also demonstrated in Figures 2 to 4.

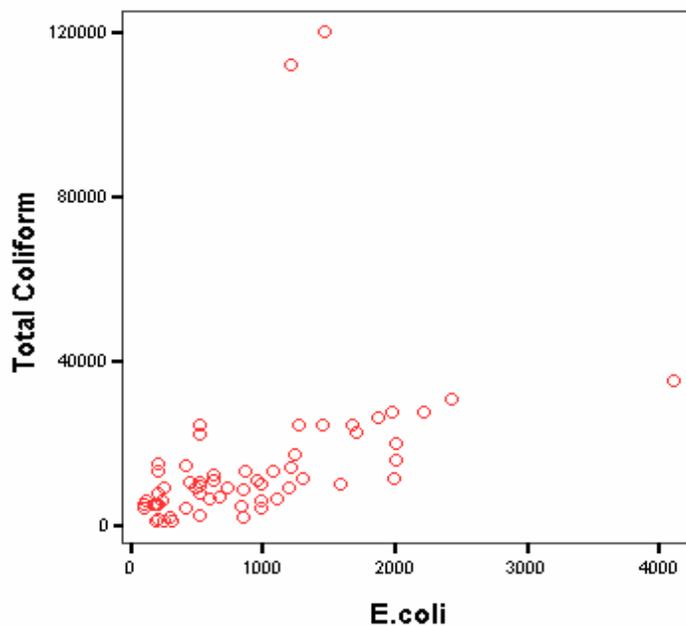
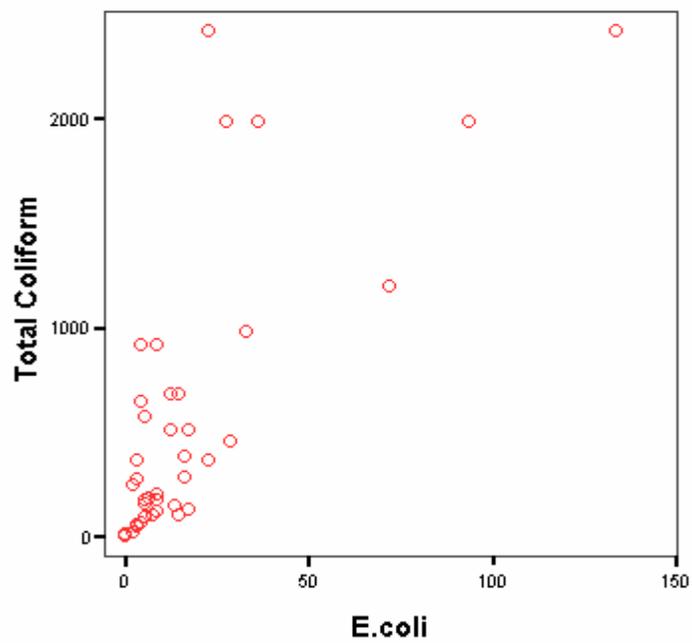


Figure 2. Relationship of *E. coli* and total coliforms in water (MPN/100 mL)



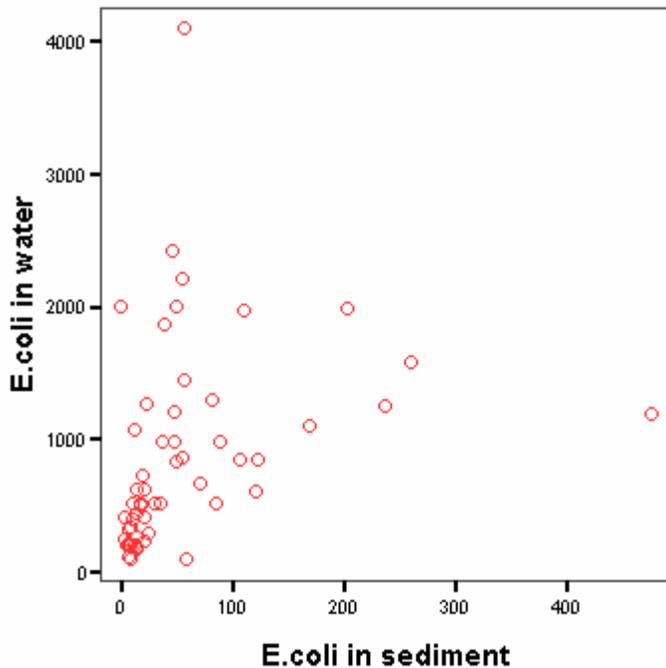


Figure 4. Relationship of *E. coli* in water (MPN/100 mL) and sediments (MPN/g dry weight)

The primary study demonstrated the spatial and temporal patterns of fecal indicator concentrations in the surface water and sediments of the Blackstone River, and also gave an indication of the source and transport pathways of the pathogens. According to the results, wet weather clearly impacts *E. coli* concentrations. Following the variation of precipitation, the number of the *E. coli* was changed accordingly. However, for the Blackstone River it is not clear that the increase of *E. coli* in the surface water is originating from the sediments as *E. coli* in the sediments followed the same general trends as for the surface water. Isolated and confirmed *E. coli* will be further analyzed by ribotyping methods.

The proposed research will provide a greater mechanistic understanding of the fate and transport of *E. coli*, a primary microbial indicator of water quality. The expected results of this investigation include a better understanding of environmental factors with respect to the numbers of pathogenic microorganisms arriving at a water treatment plant, as well as more detailed information on sources of pathogens in a complex watershed. This study will provide water managers and regulators with reliable information to help them develop strategies for source water protection for drinking water and for other important uses of the watershed such as recreation.

4. Training

One MS student was supported by the project, and one additional student was trained to conduct field and lab measurements. Both students are in the Department of Public Health at UMass Amherst.

5. Dissemination of Results

One abstract has been accepted for the upcoming AWWA Source Water Protection Conference. A manuscript has been written and will be submitted in summer 2006.

References

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