So Easy to Develop…

Pathogens (Bacteria) TMDLs

…so Hard to Improve Water Quality

EPA
United States
Environmental Protection
Agency

Outline

- Terminology and Background
- Previous Shepherdstown Discussion Recap
  - In 2017
  - In 2018
- Example: The Common Methodology
  - Load Duration Curves
  - Watershed Modeling
  - What works & what to consider when it doesn’t?
- Presentations: Marirosa Molina, EPA ORD & Molly Rippke, Michigan DEQ

Some Terms

- Pathogen: a bacterium, virus, or other microorganism which can cause disease.
- Fecal Coliform: a gram-negative, facultatively anaerobic, rod-shaped, non-sporulating bacterium. Coliform bacteria generally originate in the intestines of warm-blooded animals.
- *E. coli*: a gram-negative, facultative anaerobic, rod-shaped, coliform bacterium of the genus *Escherichia* that is commonly found in the lower intestine of warm-blooded organisms (endotherms). Most *E. coli* strains are harmless, but some serotypes can cause serious food poisoning in their hosts.
- Die-off: Bacteria die due to solar radiation and microbial predation. (Usually expressed as Time (%dead))
- Regrowth: Bacteria multiplying after die-off given appropriate conditions

Some Common Causes of Disease in Humans

- **Taken from:**
- ***Immunobiology: The Immune System in Health and Disease. 5th edition.*** Janeway CA Jr, Travers P, Walport M, et al. New York: Garland Science; 2001.

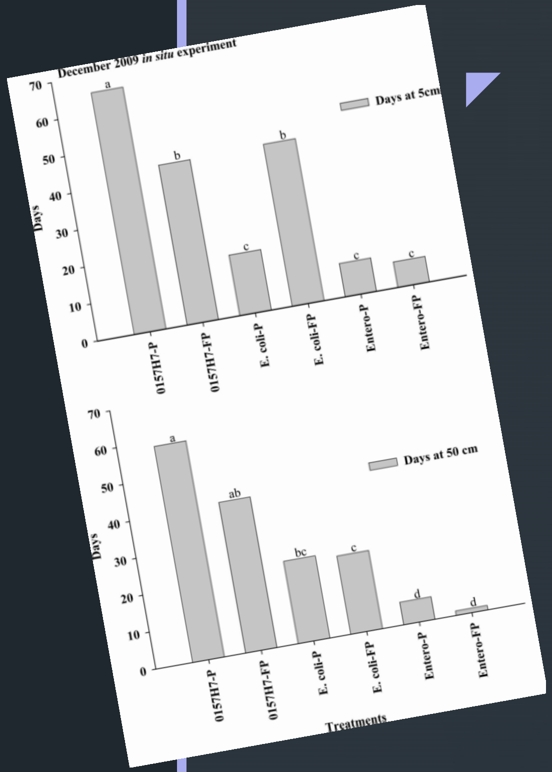
Viruses		Hepadnaviruses	Hepatitis B virus
	RNA viruses	Orthomyxoviruses	Influenza virus
		Paramyxoviruses	Mumps, measles, respiratory syncytial virus
		Coronaviruses	Common cold viruses
		Picornaviruses	Polio, coxsackie, hepatitis A, rhinovirus
		Reoviruses	Rotavirus, reovirus
		Togaviruses	Rubella, arthropod-borne encephalitis
		Flaviviruses	Arthropod-borne viruses, (yellow fever, dengue fever)
		Arenaviruses	Lymphocytic choriomeningitis, Lassa fever
		Rhabdoviruses	Rabies
		Retroviruses	Human T-cell leukemia virus, HIV
Bacteria	Gram +ve cocci	Staphylococci	*Staphylococcus aureus*
		Streptococci	*Streptococcus pneumoniae, S. pyogenes*
	Gram –ve cocci	Neisseriae	*Neisseria gonorrhoeae, N. meningitidis*
	Gram +ve bacilli		*Corynebacteria, Bacillus anthracis, Listeria monocytogenes*
	Gram –ve bacilli		*Salmonella, Shigella, Campylobacter, Vibrio, Yersinia, Pasteurella, Pseudomonas, Brucella, Haemophilus, Legionella, Bordetella*
	Anaerobic bacteria	Clostridia	*Clostridium tetani, C. botulinum, C. perfringens*
	Spirochetes		*Treponema pallidum, Borrelia burgdorferi, Leptospira interrogans*
	Mycobacteria		*Mycobacterium tuberculosis, M. leprae, M. avium*
	Rickettsias		*Rickettsia prowazeki*
	Chlamydias		*Chlamydia trachomatis*
	Mycoplasmas		*Mycoplasma pneumoniae*
			Candida albicans, Cryptococcus neoformans,

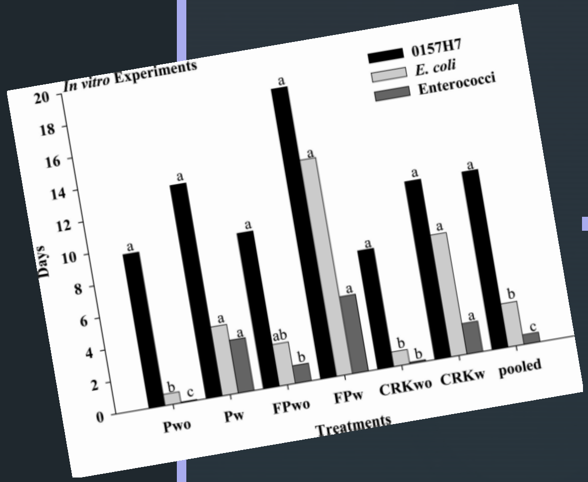
In 2017…

- Talked about bacteria from the standpoint of challenges and opportunities in WQS, Listing and TMDLs.
  - Discussed using source identification tools to refine recreational criteria and the methods used to monitor to better define circumstances where there is a human health risk.
  - Explored efficiencies in sampling by using statewide probabilistic monitoring approaches (MI) and also by engaging volunteer monitoring groups (VA).
  - Statewide Bacteria TMDLs could be a powerful tool to get a handle on the problem and implement controls. Additional details were addressed in basin-specific plans (KY, MI, CT).

In 2018…

- Held a working session to better understand some of the questions and issues people have related to bacteria.
  - Group was most interested in learning about tools and techniques to determine whether observed bacteria levels are due to human pathogens or wildlife, etc. How could that information be incorporated into WQS, assessment, TMDLs and beach closure decisions?
  - Identified areas for continued discussion and clarification - (1) Transition in bacterial indicators - what it means for listings and TMDLs. (2) Sampling considerations in regards to the duration of your criterion. (3) Monitoring strategies for bacteria.
  - Discussed other topics - Use of high flow excursion provisions, other indicators (e.g., coliphage), political issues around closures, disincentives for monitoring, and use of predictive models.





Worth Mentioning

- *E. coli* O157:H7 has been reported to have substantially different in situ die-off rates compared to commensal *E. coli* in the published literature.
  - Commensal *E. coli* seems reach 99% die off in less than 30 days in ponds.
  - Same conditions: *E. coli* O157:H7 is reported to reach 99% die off in as much as 70 days.
- Take home: Things are not always simple when we're talking bacteria.

Environ. Sci. Technol. 2011, 45, 5, 1853-1858

Regarding TMDLs

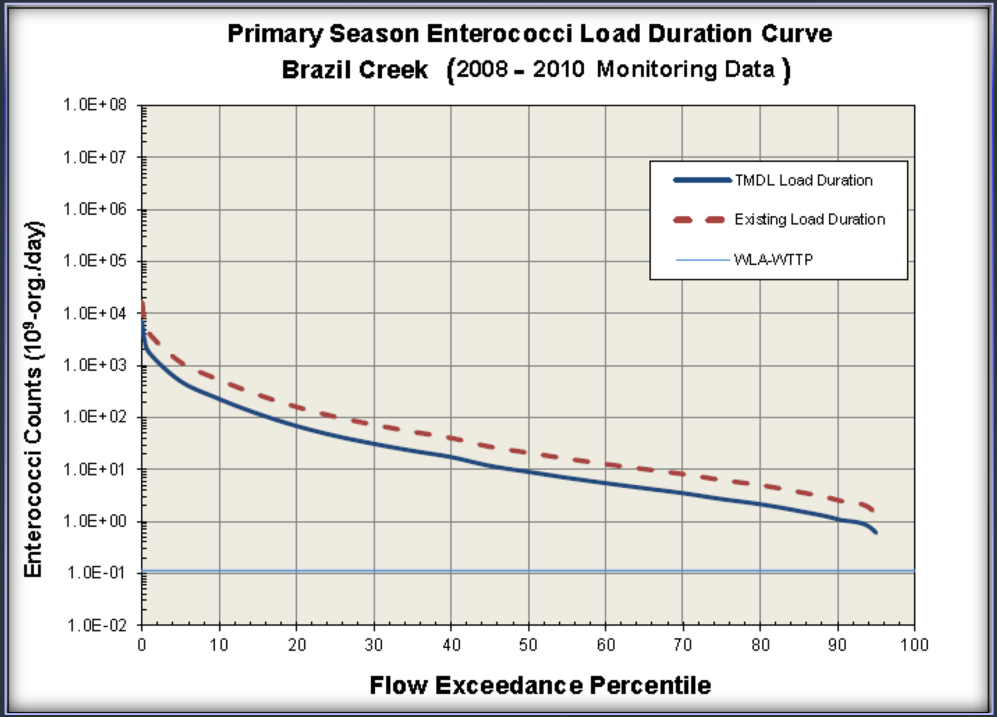
So What Do We Normally Do?

Most TMDLs Address Bacteria Using…

- Load Duration Curves
  - Bacterial TMDLs are expressed in the following formula:
  - ***TMDL (cfu/day) = WQS * flow (cfs) * unit conversion factor***
    - *Where: WQS = 126 cfu/100 mL (E. coli); or 33 cfu/100 mL (Enterococci)*
    - *Unit conversion factor = 24,465,525*
- A distant…distant… 2nd: Watershed Models (SWAT, LSPC/HSPF, etc)

Simple Tools – Load Duration Curves

- Simple tools tend to yield simple answers
- Simple is not necessarily inadequate
- Most bacteria TMDLs use a load duration approach



What About Simple Tools Work Well?

- Data requirements are minimal
  - Flow (temporal and spatial data)
  - Land use can be incorporated
- Provides information for different flow regimes
- Graphically identify conditions needing to be addressed

Bacteria in Watershed Modeling

- In general…
  - Watershed models use a simple approximations for individual reaches
    - Die-off and regrowth are not included or are averaged for the subwatershed (curve fitting)
    - Rely on calibration to capture the hydrodynamic impacts as well as ambient/biological aspects
    - Sampling is instantaneous whereas hourly or daily time steps are common for watersheds
  - Watershed approaches for bacteria tend to be representatively data poor
    - Significant if high resolution output is necessary (e.g. BMP placement)

Where Do We Struggle? (Wide Angle View)

- Source Identification
- Bacteria die-off and regrowth in a variety of waters
  - Ambient conditions
  - Spatial and temporal artifacts
  - Strain identification, if warranted
- WQS
  - 2012 Recreation recommendations (126 cfu/100 mL *E. coli* or 35 cfu/100 mL Enterococci) are implemented in 31 out of 50 states.

Questions…

Next up: presentations by Marirosa Molina, EPA ORD & Molly Rippke, Michigan EGLE