Chapter 1

BACTERIA AND WATER QUALITY

- What are Bacteria?
- What are Indicator Bacteria?
- How Do Bacteria Get Into Streams and Rivers?
- What Risks Do Bacteria Pose To Human Health?
- Georgia Bacterial Standards
- Relationship Between Fecal Coliforms and *E. coli*
- Recommended E. coli Standards for Recreational Waters
- Weather and Seasonal Influences
- Important Water Quality Parameters

What are Bacteria?

Bacteria are microscopic, single-celled organisms. They are so small that that five million could be placed on the head of a pin. Under favorable conditions they can reproduce rapidly and can form colonies that are visible without magnification. Bacteria can utilize a large variety of habitats and can survive and adapt to almost all conditions present on planet earth. They have been so successful that they are the most numerous life forms on the planet. Most bacteria are beneficial and responsible for important environmental processes such as decomposition, nutrient cycling and the breakdown of environmental toxins. Some bacteria, however, are pathogenic (or disease causing) and result in human health problems.

Coliform bacteria are members of the Enterobacteriaceae family. While some coliform bacteria can be naturally found in soil, the type of coliform bacteria that lives in the intestinal tract of warm-blooded animals and originates from animal and human waste is called fecal coliform bacteria. *Escherichia coli* (*E. coli*) is one subgroup of fecal coliform bacteria. Even within this species, there are numerous different strains, some of which can be pathogenic. The mere presence of these naturally occurring organisms in the environment is generally not a cause for alarm unless they appear in numerical levels that exceed US EPA recommended limits.

What are Indicator Bacteria?

An indicator organism signals that certain conditions exist in the environment. The presence of fecal coliform bacteria indicates the possible presence of pathogens. Trying to detect disease-causing bacteria and other pathogens in water requires considerable training, time and expense. The US EPA recommends *E. coli* bacteria as good indicator organisms of fecal contamination because they are associated with warm-blooded animal wastes, generally live longer than pathogens, are found in greater numbers and are less risky to culture in a laboratory than pathogens. However, their presence does not necessarily mean that pathogens are present, but rather indicates a potential risk to human health. Monitoring for these indicator organisms is an easy and economical method for citizens or professionals to assess health risks due to bacterial contamination of surface waters. If bacterial contamination of surface water is found, other disease-causing organisms such as viruses and protozoans may also be present in these wastes and pose a health threat.

How do Bacteria Get into Streams and Rivers?

E.coli in waterways can originate from the intestinal tracts of both humans and other warm-blooded animals, such as dogs, cats, livestock and wildlife. Human sources include failing septic tanks, leaking sewer lines, wastewater treatment plants, sewer overflows, land application of biosolids, boat discharges and urban storm water runoff. In urban watersheds, fecal indicator bacteria are significantly correlated with human density (Frenzel and Couvillion, 2002). Possible animal sources of fecal coliform bacteria include cattle in streams, land application of animal waste, dairy operations, poultry operations, hobby horse farms, dog and cat waste from parks, lawns, streets and wildlife such as geese, pigeons, ducks, deer and raccoons.

Fecal material as well as other pollutants can be transported to waterways through runoff from rain events. How quickly pollutants are transported partially depends on the type of land use. Grasses and vegetated land tend to soak up rainfall, thereby increasing infiltration into the ground and reducing runoff to waterways. Developed lands such as streets, rooftops, sidewalks, parking lots and driveways create more impervious surfaces thereby increasing runoff. Lands that support animals such as cattle, hogs or horses can also be a source of bacteria, particularly if animals enter the water for drinking or if heavy rains wash manure from the land into receiving waters.

Another source of bacterial pollution to stream waters originates from point sources, such as the discharge of pollutants through a pipe. Bacteria can enter waterways from broken pipes, illicit connections and stormwater outfalls. Additionally, large rain events, power failures or maintenance problems can cause wastewater treatment plants to discharge partially treated sewage directly into rivers and streams due to the excessive volume of water entering the plant.

What Risks Do Bacteria Pose To Human Health?

People should be aware of the risk that high bacterial levels may pose to human health. The higher the bacterial levels, the greater the potential health risk for gastroenteritis, a condition indicated by vomiting, diarrhea, fever, nausea and stomachache; skin disease; and respiratory, eye, ear, nose, throat and skin infections. While *E. coli* by itself is not generally a cause for alarm, excessive levels of *E. coli* may indicate the presence of pathogens such as harmful bacteria *E. coli* 0157, *Salmonella* and *shigella* (which can cause gastrointestinal illnesses), *Psuedomonas aeruginosa* (which can cause swimmer's ear or dermatitis), protozoans such as *Cryptosporidium* and *Giardia* and viruses such as hepatitis A.

Georgia Bacterial Standards

The State of Georgia uses fecal coliform as the water quality standard for bacterial contamination. The chart below shows an outline of fecal coliform standards set by the state. The standards were established to support the requirement by the US EPA to protect all waters for use of primary contact recreation or swimming. Fecal coliform levels are determined by use classification for all bodies of water.

Georgia Fecal Coliform Standards

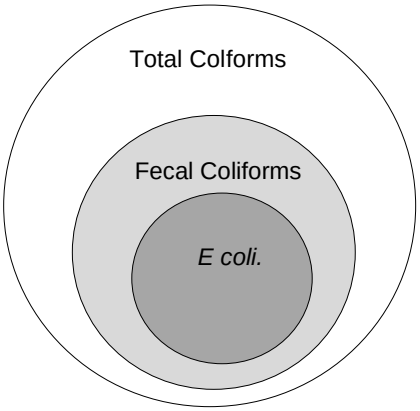
	Bacteria Levels (Fecal coliform)	
Use Classification	**30-Day Geometric Mean (cfu/100 ml)**	**Maximum (cfu/100ml)**
Drinking Water requiring treatment	1,000 (Nov-April) 200 (May-Oct)	4,000 (Nov-April)
Recreation	200 (Freshwater) 100 (Coastal)	--
Fishing Coastal Fishing	1,000 (Nov-April) 200 (May-Oct)	4,000 (Nov-April)
Scenic River	No alteration of natural water quality	
Wild River	No alteration of natural water quality	

Relationship between Fecal Coliforms and *E. coli*

Fecal Coliforms are a form of coliform bacteria, and as its name implies, it originates from fecal matter. *E. coli* is a species within the fecal coliform bacteria that originates from the waste of warm-blooded animals and is estimated to be about 60 – 80% of the fecal coliform value (See illustration).

The US EPA recommended conversion factor between fecal coliform and *E. coli* is 126/200, which results in an *E. coli/*Fecal Coliform (EC/FC) ratio of 0.63. However, a recent US Geological Survey paper showed the EC/FC ratio to be closer to 0.77.

Because *E. coli* is related more closely with swimming-related gastrointestinal illnesses compared to fecal coliforms, the US EPA has recommended *E. coli* as an appropriate indicator species for assessing potential health risks for recreational waters.



General organization of coliform bacteria

Recommended *E. coli* Standards for Recreational Waters

The US EPA recommended *E. coli* as the freshwater quality criterion for bacteria in the *Ambient Water Quality Criteria for Bacteria* document published in 1986 - a departure from earlier recommendations of total coliform and fecal coliform. The *E. coli* recommendation resulted from epidemiological studies that found that *E. coli* was statistically correlated with swimming-related gastrointestinal illnesses.
i

EPA's recommended limit of *E. coli* within recreational waters such as swimming and water skiing (full body contact) within recreational waters is equal to or less than 126 cfu/100 ml (colony forming units per 100 milliliters of water) based on a geometric mean or a one-time measurement equal to or less than 235 cfu/100 ml. EPA recommends a set of standards for *E. coli* in fresh water bodies as a single maximum allowable count. These rates correspond to an acceptable risk level of 8 people out of 1000 getting sick.

	Designated Swimming	**Moderate Swimming Area**	**Light Swimming Area**	**Infrequent Swimming Area**
***E. coli* (cfu/100 ml)**	<235	<298	<410	<576

(from US EPA 1986, 2002a)

Even with good watershed management measures, there will always be fecal bacteria in the environment. However, if you repeatedly find unusually high levels of *E. coli* on a long-term, regular basis in your river, lake or beach, you should alert and work with water agencies, health departments, local governments, watershed groups and community leaders to identify and correct the problem. To find more information on *E. coli* levels that warrant action according to Georgia Adopt-A-Stream, see Getting "High" Bacteria Counts in Chapter 2.

Weather and Seasonal Influences

Weather and seasonal effects influence the level of bacteria. This natural variability makes the bacterial concentrations in waterways difficult to predict at any one time. Bacteria numbers often increase following a heavy storm or other excessive runoff event. *E. coli* bacteria are often more prevalent in turbid waters because they live in soil and can attach to sediment particles. Bacteria can also remain in streambed sediments for long periods of time. If the streambed has been stirred up by increased flow or rainfall, your sample could have elevated bacteria levels. This is why you should avoid disturbing the streambed as you wade out into the stream and be sure to collect the water sample upstream from you. If you are collecting at several sites within the stream, collect the furthest downstream sample first and proceed upstream.

A number of other environmental factors will affect bacteria survival in waterbodies. *E.coli* counts are often higher during the summer months compared to lower counts during the winter months. Higher *E. coli* counts may be found in warmer waters because *E.coli* survive longer at its optimal growth temperatures (*E. coli* are adapted to living in the warm environment of the intestines of warm-blooded animals). However, ultraviolet light from the sun can kill bacteria in clear streams, rivers or lakes.

Additional Water Quality Parameters

A comprehensive assessment program of stream water quality should consider monitoring for other water quality indicators. A combination of biological, chemical and physical factors can indicate if a waterbody is degraded or polluted. How the water will be used (drinking, swimming, etc.) may influence which characteristics are used to determine water quality.

In addition to bacteria, Adopt-A-Stream recommends chemical testing for basic parameters including dissolved oxygen, temperature, conductivity and pH which are discussed in detail in the *Macroinvertebrate & Chemical Monitoring* manual. Other common water quality measurements include clarity and nutrients (particularly nitrogen and phosphorus) and macroinvertebrate biological communities. Recording visual observations of your monitoring site also provides vital information for assessing the waterbody. To provide volunteers with background in visual waterway assessment, Adopt-A-Stream offers a *Visual Stream Survey* manual and accompanying workshop.

Many of the potential land use activities that will impact your stream, lake or coastal area can be pinpointed by carefully analyzing human activity within your watershed. Determining land uses within your watershed can give you a better picture of the potential sources of pollution to your waterbody. The Watershed Survey and Map Assessment located in the *Getting to Know Your Watershed* manual provide guidance on what activities and land uses to note.

Typical Ranges for Recreational Water in Georgia

Dissolved Oxygen (mg/L)	Temperature (°C)	Conductivity (μS/cm)	pH
5-6, up to 14.6	Not to exceed 32°C	0 – 1500	6-8.5, can be as low as 3.5

Different water quality standards exist based on many of these parameters, however the standards may vary depending on the use of the water such as drinking water versus irrigation water.

For more information on our chemical, macroinvertebrate or visual stream monitoring programs, please contact Adopt-A-Stream. Georgia Adopt-A-Stream has developed several manuals to assist volunteers in their monitoring efforts. These manuals include *Getting to Know Your Watershed, Visual Stream Survey, Macroinvertebrate and Chemical Stream Monitoring, Educator's Guide* (for grades K-12), *Amphibian Monitoring, Wetland Monitoring*, and *Adopt-A-Lake*.