Why Test for Bacteria using BARTs?

Gradually, the role of bacteria in the myriad of natural and engineered events are becoming appreciated. These range from the obvious (e.g., taste, odor, corrosion and slime formation) to the subtle (e.g., bioaccumulation and occlusion). Virtually any management practice involving water could be subjected to the impacts of bacteria and other microorganisms, and BART testing provides a means to monitor either the state of the microbial population or the impact of treatment.

For managers of water systems, there is a need to understand the potential and real challenges that can be caused by these nuisance microorganisms. Unfortunately, very often, microbiological fouling of a system (whether the base medium is water, oil or gas) is slow and covert without any obvious signals to show that it is microbial in origin. Often, these degenerative processes are put down to the normal aging of the facility and it is now considered that these processes could be driven by microbes and managed by monitoring the levels of population in these nuisance bacterial events using the BART tests.

Who should use the BART tests? Anyone who understands that bacteria and other microbes can affect the lifespan of a facility in a very real manner. These effects can range through a whole range of characteristic changes including:

- Corrosion in which the microorganisms corrode the solid structures (e.g., steel or concrete) in such a manner as to severely weaken the structure causing failure.

- Plugging, in which the microorganisms form thick biofilm growths (slimes) within porous media, which cause significant losses in conductivity (hydraulic or thermal).

- Radical changes in water quality caused by the casual sloughing of the slimes which are loaded with microbial cells and their associated accumulates. This sloughing can cause sudden dramatic changes in the concentrations of some chemicals (e.g., iron and phosphorus) in the water.

- False data generation due to the biofilms within the upstream zone above the site of special interest. These biofilms (or slimes) can accumulate very large concentrations of recalcitrant chemicals that would otherwise have found their way into the sampling site. This is a form of bio-filtration and accumulation which gives a falsely improved water quality until the growths begin to slough. Monitoring wells may be particularly prone to these events when organic pollutants (e.g., BTEX, PAH, VOH) approach the well and are accumulated into the biofouled zone around the well. This biological interface acts as an effective filter until maturation causes the collapse of the biofilm structures.

- Odors can be generated by a whole range of microorganisms with some well known odors being:

    1. rotten egg (SRB generating hydrogen sulfide),
    2. fishy (commonly heterotrophic aerobic bacteria and, in particular, *Pseudomonas* species),
    3. earthy-musty (geosmins generated primarily by the *Streptomyces*),
    4. septic (generated by various members of the enteric bacteria including the coliform bacteria)
    5. vegetable/fruity odors (from a variety of algae and yeast).

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One useful tool to aid in the confirmation of the source of odors is that the odors will concentrate between the outer tube and the inner test vial of the BART test when odor-generating microbes have grown in the tester. Loosening the outer cap and cautiously sniffing the gap between the cap and the outer tube will reveal the types of odors being generated by these microbes. Often this smell is coincident with an odor being detected in the sample itself. This can often convince a doubter that it is the microbes in the BART that are capable of causing the odor problem and a focus on managing the problem is now understood.

- Turbidity has often been thought of as simply a chemical event associated with chemical colloids, silts or precipitation. These will cause the sample to go cloudy. More commonly than not, the cloudiness in the sample is a combination of turbulence swirling up sediments into the liquid medium and the growth of microbes within that sample. If the cloudiness is microbial, then it can be expected that the BART tests will detect very aggressive microbial populations.

- Color is most commonly generated by microbes through the accumulation of iron (yellows, browns, reds and oranges) although occasionally pigment can be generated by the microbes themselves as pigments. These pigments are most commonly browns, yellows, greens, blue- greens and reds and are generally more transient.

- Biodegradation is a major industry today as a part of the environment industry. Where there is a biologically driven degradation occurring, there is an inevitable increase in the population of those microbes in the environments that are associated with an observed degradation. To monitor these populations, the BART tests can be used. Generally, if the degradation is basically aerobic and involves a narrow spectrum of organic pollutants, then the heterotrophic aerobic (HAB), the fluorescing Pseudomonad (FLOR) and the slime-forming (SLYM) BART testers are most likely to detect the increased aggressivity of the degraders. This can then be used as a "benchmark" for the vitality of the microbial consortium causing the degradation. If the degradation is anaerobic, then a different spectrum of bacteria may be the most aggressive. These could include the sulfate-reducing (SRB), the slime-forming (SLYM) and the denitrifying (DN) bacteria.

The BART testers are suitable as a field test for any manager or consultant concerned about managing problems which are likely to be either instigated by, or worsened by, the presence of the various groups of microorganisms detectable using the BART testers. Just who would use the BART testers would depend upon the level of biological activity occurring whether this be biofouling, biofiltration, or biodegradation. Some examples of who would use the BART tests are listed below:

- **Water Well Operators**
  Water wells are a "site unseen" operation. The extent of any visible fouling is limited to camera logs down the well or obvious fouling of filters and lines downstream of the well head. Often, the bulk source of all of the biological activity is outside of the well screen and not visible. What is visible is the "tip of the iceberg" which is the colloidal structures floating in the well water column (well snow), encrustations, tubercles and slimes attached to the walls and screens of the well and as deposits in the bottom of the well. Detecting even the most aggressive bacteria under these conditions is not simple. The bacteria often have to be "tricked" by changing the normal operational procedures for the well in order to be able get them into the water so that they can be detected using the BART tests. Most commonly used of the BART tests are:

  IRB (where there are known iron problems);

  SRB (where there are anaerobic, black water and corrosion problems);

  SLYM (where there are slimes forming in and over the well casing, screen or pump); and HAB (if there is turbidity, odd odors, cloudiness, fluorescence and high organic loadings in the water).

- **Water Treatment Plant Operators**
  Water treatment facilities usually involve water that has become aerated, possibly filtered, disinfected, clarified and stored. It should be remembered that the BART tests are proofed against the possible effects of chlorine-based disinfectants by the inclusion of a neutralizer that is effective for concentrations of up to 5,000 ppm of chlorine (sodium thiosulfate pellet). In general, apart from the concern for the elimination of coliform bacteria from the water, there is little regulated limitation to the microbial loadings in potable, industrial and recreational waters. Consequently, the need to monitor nuisance microbes is more in the interest of the operator rather than regulatory compliance. Unfortunately, the common attitude that water should be free disenfranchises the ability of the operator to assure a maximum operational efficiency in favor of bulk acceptable water produced at the lowest cost. Biofouling causes many covert (and commonly negative) impacts which often go unnoticed until it is too late to effectively control and then radical "surgery" has to be performed to replace the fouled parts. Common problems relate to massive slime formations (SLYM and HAB are good for checking this), corrosion of equipment (SRB), encrustations in pipes, tanks and filters (IRB and FLOR), and sudden fluctuations in water quality (HAB, SRB and DN). Fluctuating nitrate problems could be related to changes in the biofouling with a greater probability of nitrate expression in waters high in oxygen and low in organics. The organics would trigger a greater rate of enitrification particular under a suppressed oxygen regime. Routine use of BART tests in the ongoing operations of the treatment plant can allow earlier control of potential serious biofouling events.

- **Bottled Water Plant Operators**
  Bottled water represent a growing fraction of the consumed water since it reflects a superior product in the minds of the consumer to potable water supplies provided by local agencies. While ozonated and carbonated waters do have the microbial loadings suppressed to varying degrees depending upon the techniques employed, there is still a potential for the water to degenerate as a result of microbiological activity. Most commonly, this will take the form of clouding, deposits, tastes and odors. If these events occur when the product is already with the distributor or final retailer, then this would have serious consequences for the bottling company. Quality assurance and quality control can be achieved using the BART tests to determine that the source water is not fouled with aggressive bacteria and that the ozonation or carbonation has effectively acted as a disinfectant to suppress the nuisance microbes.

- **Environmental Managers**
  The largest biomass by far on Earth belongs to the microorganisms. This group is not sitting there passively while the biota (animals and plants) quietly does all of the "work." Microorganisms are ubiquitous and functionally active whether they are in the human body (90% of the cells in the human body are microbial cells), in soils, waters, oil and gas, muds and sedimentary rocks. Environmental managers face the task of "managing" the environment and it is essential that the role of microorganisms in that environment be recognized. The BART tests offer the potential to take "snapshots" of the population of the various components in the microbial biomass that can have a significant impact on the environment of concern.

- **Sanitary Landfill Operators**
  There are a number of microbial challenges faced by sanitary landfill operators simply because of the highly organic nature of the fill materials deposited in the landfill. In going down through a landfill, there are a series of stratified activities predominantly microbial in form. These include (going from the top down):

  - Surface growths on the redox front dominated by methanogenic bacteria that are able to degrade methane.
  - Biogas generation zone in which methanogenic bacteria are very active producing copious quantities of methane.
  - Drainage systems in which bacterial activity causes the generation of thick plugging slimes (dominated often by SRB and SLYM bacteria). Should these growths get too aggressive, then there could be reduced permeability that would lead to the water mounding in the landfill and breaking out through side erosions.

- Leachate outflows from the drains. Very aggressive aerobic activity is likely to occur around the redox fronts at these sites leading to radical nitrification (nitrate production) and heavy slime growths (dominated by HAB, SLYM, FLOR and IRB).

Both the functionality and stability of sanitary landfill operations can be severely compromised by aggressive microbial activities. An ongoing monitoring of these nuisance microbial groups using the BART testers can aid in predicting and controlling problems before they become uncontrollable.

- **Operators of Recreational Waters**
  These waters range from spas, swimming pools, hot tubs and beaches. With these waters there is a primary concern to reduce the hygiene risks to the users by the routine examination for coliform bacteria. However, there are other problems particularly with hot tubs, swimming pools and spas that are caused by other nuisance bacteria that can be detected using the BART tests.

  The effects of the nuisance bacteria would fall under the categories of reducing plant efficiencies, reducing water quality, and generating unacceptable slime growths. There are both economic and user acceptability issues involved in the microbial biofouling problems which can be monitored and managed using the BART testers.

- **Irrigation Operators**
  Vast volumes of water are used in the irrigation industry. This water is subjected to radical changes in pressures and flow rates often under increasingly oxidative conditions. Such shifts in conditions can cause a focusing of microbial slime growths within the system and nozzles that can radically reduce efficiencies and increase operating costs. Most commonly, the SLYM and IRB are likely to dominate under low iron and high iron conditions respectively. If there is a low oxygen concentration in the water, high sulfates or hydrogen sulfide “rotten” egg odor, black water), then the SRB may be dominant in the irrigation system. Cleanliness and sanitization of the equipment (confirmed by the routine use of the BART tests) is likely to pay dividends through improved efficiencies and higher quality water for irrigation.

- **Hazardous Waste Site Operators**
  While these sites may be very hazardous to humans, the environments created may be very conducive to extensive microbial activity. Such activity can be related to the rates of biodegradation and bioaccumulation activities being generated by the naturally attenuated consortia active at the site. Additionally, the operation of treatment facilities, injection and recovery wells, distribution lines and storage tanks can all become severely compromised. For example, returning treated water via the injection wells often becomes highly aerated. Upon injection, a redox front forms around the well in which bacterial slimes grow causing erratic losses in permeability. For the operator of hazardous waste sites, the BART tests provide a simple monitoring tool to determine the level of bacterial activity occurring when used routinely. Management of the site can subsequently be improved through this routine monitoring of the population levels (most simply monitored by the time lags observed).

- **Cooling Tower and Heat Exchanger Managers**
  As a matter of routine, water is used as the heat sink in many processes. The heat in that water is removed to the air (e.g., cooling tower) or to a greater volume of water (e.g., heat exchanger). For the heat to move efficiently in the transfer from the water to the receiving medium, there should be no interferences. Biofilms (slimes) forming at these interfaces can severely reduce this heat exchange in several ways. Failure to control these biofilms can be expensive due to losses in the process efficiency that causes equipment to fail to meet specifications. Controlling the biofilms is usually achieved by the application of biocides. By the routine testing of the waters using the BART tests, the effectiveness of the biocides in suppressing the biofilms can be determined conveniently and easily.

BART™ Application Guide

APPLICATIONS	Problems Associated with Bacterial Growth	BART™ To Use
Aquaculture	Algal blooms can deplete oxygen supplies	ALGE, N, HAB
	and produce toxins	
Cooling Towers and Heat Exchangers	Spoilage of cooling tower waters, which necessitates costly dumping Corrosion of equipment	IRB, SRB, SLYM, HAB, DN, N
Drinking-Water Well Drilling	Corrosion and plugging of wells Masking of coliform bacteria	IRB, SRB, SLYM, HAB
Farms and Private Wells	Corrosion and plugging of wells and distribution lines Fluctuation of iron and maganese levels Nitrification levels of soil	IRB, SRB, SLYM, HAB, N
Hazardous Waste Treatment Facilities	Biofouling by anaerobic and aerobic bacteria, from extraction to treatment	IRB, SRB, SLYM, HAB
Municipal Water Treatment (Drinking Water and Wastewater)	Regrowth in distribution lines Offensive taste and odor in potable water Corrosion of pipes and fixtures Biofouling and corrosion of wastewater treatment equipment	IRB, SRB, SLYM, FLOR, HAB, DN, N
Petroleum: Oil Field Drilling and Refining	Plugging of wells Corrosion of pipes	IRB, SRB, SLYM
Pools and Spas	Unsanitary conditions harbor disease	POOL, HAB
Power Plant Utilities	Biofouling Corrosion and plugging of pipes, which reduces efficiency	IRB, SRB,SLYM, HAB
Process Water (Manufacturing)	Corrosion and plugging of pipes, which reduces efficiency	IRB, SRB, SLYM, HAB, DN, N
Pulp and Paper Plants	Plugging of pipes, reduced capacity Speckled, poor-quality paper products	IRB, SRB, SLYM, DN, N
Water Treatment Chemicals and Conditioning	Biofouling and corrosion of cooling tower, boiler, and home water systems	IRB, SRB, SLYM, HAB