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Looking Ahead: New Development in Beach Water Quality Monitoring and Bacterial Source Identification

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4.3 New Development in Beach Water Quality Monitoring and Bacterial Source Identification

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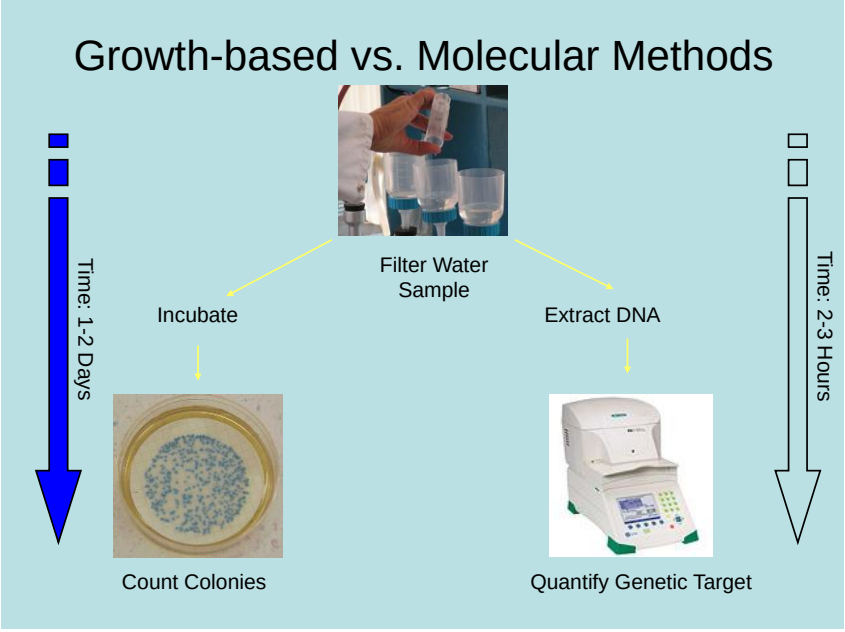
California has the most comprehensive beach water quality monitoring program in the nation. Water quality at California beaches is typically assessed using growth-based measurements of fecal indicator bacteria (FIB) including total coliform, fecal coliform and enterococci. Despite their wide use, growth-based methods are too slow to protect beachgoers from exposure to contaminated water because they require an 18-24 hour incubation period to produce an answer, and most contamination events last less than one day. Thus, swimmers are exposed to contaminated water during the incubation period and oftentimes warned to stay out of the water after the risk has abated.

New faster methods for measuring FIB are now available. In 2012, the United States Environmental Protection Agency (EPA) published new rapid molecular methods for measuring Enterococcus using quantitative polymerase chain reaction (qPCR). These methods do not rely on growth and can be performed in the laboratory in about 2 hours. Known as EPA Method 1609 and 1611, the methods detect and quantify specific gene sequences in bacteria, acceptable levels of which were determined through epidemiology studies (Figure 4.3-1).

Figure 4.3-1. Comparison of growth-based vs. molecular measurement methods for enumerating bacteria in beach water. *Data Source: SCCWRP.*



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LOOKING AHEAD: Beach Water Quality Monitoring

Despite the increased speed of measurement using qPCR, agencies that conduct beach water quality monitoring have been slow to adopt the new methodology. To date, only three Southern California counties (Los Angeles, Orange and San Diego) have conducted exploratory studies, and only one of these (Orange) has actually used qPCR results to make beach management decisions (Griffith and Weisberg 2011).

There are three types of impediments to agencies adopting qPCR, though none are technical. The first is regulatory. The California Department of Public Health has not yet approved qPCR for beach water quality monitoring and there is no laboratory training or certification program yet in place. Although the State Water Resources Control Board (SWRCB) is moving to revamp the Environmental Laboratory Certification Program, they are at the beginning of this process and it is unclear when and how laboratories will become certified to perform qPCR. There is as yet no estimate for when the Department of Public Health may approve qPCR. The next type of impediment is financial. Funding for beach water quality monitoring was cut drastically during the recession years. Many agencies reduced staffing or instituted hiring freezes during this time. The result was a commensurate decline in beach water quality monitoring efforts and many programs have not yet recovered. Thus, agencies that once tested beach water multiple days per week have cut their monitoring effort to once per week, and some agencies have stopped monitoring water quality altogether during the winter months. An additional disincentive to adopting a new methodology is created by training costs and the fact that setting up a new lab to conduct qPCR can require up to $100K in capital expenditures for equipment and laboratory modifications. There is also the cost of implementation. In order to gain approval to use qPCR at a particular beach, monitoring agencies must run qPCR side-by-side with a growth-based method for an entire season to demonstrate that the methods produce similar results. This requirement means an additional cost, as labs would have to add staff to maintain the old method on top of the increase in training and capital costs. The last impediment is practical. It makes little sense for agencies to adopt a more rapid measurement method if the results are to be used to extrapolate water quality for an entire week. Together, these impediments have stalled adoption of qPCR for beach water quality monitoring in California for the time being.

Despite the obstacles to adoption of qPCR, one agency, the Southern California Coastal Water Research Project (SCCWRP), was able to demonstrate its possibilities. Using funding from a State of California Clean Beaches Initiative Grant, SCCWRP trained and equipped three water quality monitoring labs with varying levels of experience to conduct qPCR at nine beaches five days per week. After an initial training and evaluation period, the labs were able to routinely produce consistent qPCR results and, working with public health officials in Orange County, notify the public of poor water quality before noon of the same day (Griffith and Weisberg 2011) (Figure 4.3-2). This was important because a task force consisting of stakeholders from the monitoring, regulatory, public health, business, and environmental communities asserted that there

was little benefit to producing a rapid water quality result if the public could not be notified before they entered the water. During the summer in Southern California, a majority of swimmers do not enter the water before noon and are often heading home by late afternoon. Thus, noon is the critical cutoff for imparting water quality information.

Figure 4.3-2. Electronic sign at Huntington State Beach providing near real-time water quality information to beachgoers. *Photo Credit: John Griffith.*

One outstanding technical question about qPCR is how it will perform across the different beach types found in Southern California. To date, studies have been conducted at only a handful of beaches across the region, and there is not enough data to help predict if the method will perform as expected at any given beach type (embayment, open coast, etc.). For example, one of the important technical issues surrounding the qPCR method is termed 'inhibition'. Inhibition occurs when constituents such as humic or fulvic acids found in environmental water samples interfere with the chemistry of the PCR reaction, which can lead to underestimation of the target. However, it is unclear if this occurs more often at a particular type of beach. To help answer this question, the Microbiology Group from the Bight '13 Regional Monitoring Study organized by SCCWRP is collecting water samples at a variety of beach types from Ventura to San Diego. SCCWRP has trained these agencies in conducting qPCR, and the results are expected to shed light on the performance of the qPCR method across the different beach types in the region. When the current impediments to adoption ease, agencies will already have information about where they are likely to be most successful employing the method.

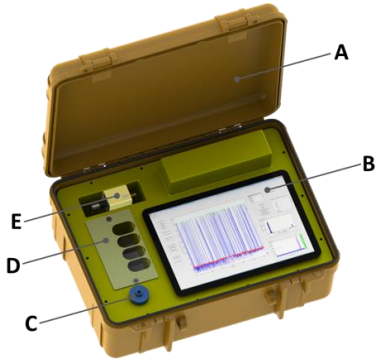
LOOKING AHEAD: Beach Water Quality Monitoring

In addition to the use of qPCR for beach monitoring, this same technology can be used with only minor modifications to identify sources of fecal contamination in beaches from land-based sources, an application where the impediments delaying implementation of qPCR for beach water quality monitoring do not apply. A recent evaluative study identified sensitive and specific bacterial markers for fecal contamination from humans, cattle, dogs, and waterfowl, and agencies are eager to use them to solve bacterial pollution problems (Boehm et al. 2013). To this end, the SWRCB funded SCCWRP to produce the *California Microbial Source Identification Manual*, which describes a tiered approach to microbial source identification (Griffith et al. 2013). Thus, as more agencies become proficient in the use of qPCR for beach water quality monitoring, beach managers will be able to leverage this expertise to identify and mitigate sources of bacteria to beaches.

Although qPCR was only recently approved by the U.S. EPA for beach monitoring, improved PCR technology is already on the horizon. Digital droplet PCR (ddPCR) is similar to qPCR in that it can detect and quantify the same set of targets. However, unlike qPCR, ddPCR does not require the user to produce a standard curve from reference material for quantification, and is much more resistant to inhibition than is qPCR. Recent studies have shown that ddPCR is able to produce similar but more precise results than qPCR when run in parallel on the same samples, especially when concentrations of the target organism are low (Cao et al. 2014).

While ddPCR improves on the quantification and precision of results compared to qPCR, it does not solve the problem of getting samples from the beach to the lab in time to issue water quality warnings by noon. Further, it is not financially feasible to send individual water samplers to each beach site to speed up data production as was done in SCCWRP's demonstration project. To address this time issue, SCCWRP and its partners at Monterey Bay Aquarium Research Institute and Arizona State University, are developing automated ddPCR technology designed for use in the field. About the size of a small suitcase, the automated ddPCR device would enable beach water quality measurements to be initiated by lifeguards or analyzed while a beach sampler is driving from site to site (Figure 4.3-3). Results would then be telemetered to the lab or public health officials where they could be acted upon in real time. Equally as exciting, the automated ddPCR device could be used by investigators in the field to follow the trails of fecal bacteria directly back to their source.

Figure 4.3-3. Conceptual rendering of a ddPCR device. A) Portable brief-case format digital PCR device with external power outlet; B) The tablet PC with control and data analysis; C) The sample injection port; D) The rapid-replace consumable reagent bay; and E) The target primer library. *Photo Credit: Cody Youngbull, Arizona State University.*



There is now broad consensus in the research community that PCR-based methodologies and tools represent the future of bacterial monitoring and source identification. The newest of these

technologies have been demonstrated to be at least as quantifiable and precise as traditional growth-based measurement, and much faster in producing results. Although the initial transition and set-up cost may be high, use of the new methodology will also be more cost-effective in the long-term. Suffice it to say that wide adoption of the new methodology will only be a matter of time. Hopefully, more federal, state, and local support will help to accelerate the process.

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