Tackling Beach Closures and Coliforms

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Research evaluating pollutant removal efficiencies for stormwater treatment systems (best management practices or BMPs) have focused primarily on physical and chemical contaminants such as total suspended solids, nutrients, and metals. Relatively little information has been collected about treatment efficiencies of BMPs for the removal of microbial pathogens—organisms known to be present in stormwater which pose serious health risks to high-risk groups, including the elderly and those with weak immune systems. To date, little research has been conducted to evaluate the effectiveness of current regulatory criteria for stormwater treatment systems in the removal of human microbial pathogens.

Public health warnings posted at California beaches became a sign of the times as development increased in the late 20th century. In that state, the city of Encinitas is fighting to make its star attraction, Moonlight Beach, clean and safe for visitors by using an innovative urban-runoff treatment system. At the same time, the California city of Dana Point was faced with the same problems at its star attraction, Dana Point Beach.

In Florida, state regulations (Chapter 17-40, Florida Administrative Code [F.A.C.]) recommend that stormwater treatment systems achieve an annual average of 80-percent pollutant load reduction. This standard is based primarily on the removal of heavy metals and nutrients (nitrogen and phosphorous) and does not specifically address microbial pathogens. Although standards for bacterial indicators (total and fecal coliforms) exist for surface waters, there are no maximum contaminant levels for a wide range of specific waterborne pathogens, including other species of bacteria (*Clostridium, E. coli, Salmonella, Klebsiella*), viruses (hepatitis a, Coxsackie, rotavirus), and protozoa (*Cryptosporidium, Giardia*) that can cause human disease.

The state of Florida does not explicitly require any monitoring of ocean and bay coastal waters. The Florida Department of Environmental Protection (FDEP) has bacteria standards specifically for marine waters designated for swimming, but the FDEP's monitoring is not directed toward swimmer safety at recreational beaches, focusing instead on environmental protection. Of Florida's 35 coastal counties, only nine conduct monitoring for swimmer safety.

Methods

Studies conducted by the Southwest Florida Water Management District demonstrated that some of the standard stormwater treatment such as sand filtration, wet detention, and alum injections were effective in removing microbial indicators.

Sand filtration was found to have removal efficiencies ranging from 59.4 percent to 99.5 percent and was greatest for the *Cryptosporidium* surrogate, followed by MS2 coliphage, fecal coliforms (FC), and total coliforms (TC).

In wet detention, the removal efficiencies were found to range from 64 percent to 98.2 percent. Removal efficiencies were typically greater for *Cryptosporidium*, followed by MS2, FC, and TC.

For alum coagulation, the efficiencies ranged from 84 percent to 98.4 percent. In the low-dose (10 mg/L) jar tests, greater than 3-log reductions were observed for TC, FC, and MS2 within the first 24 hours. After 48 hours, removal efficiencies (differences between the control and alum-treated sample concentrations) for most parameters except TSS and fluorescent beads had declined.

In all three of these cases, the removal efficiencies were rather high but very inconsistent. As a matter of public health and safety, it is paramount to have stable removal efficiency throughout the treatment process; therefore, other methods needed to be investigated to provide the level of safety.

Moonlight Beach, California

In one of its early efforts in the late 1990s, Encinitas adopted one of the most aggressive urban-runoff programs in the country. City staff members investigated pollutant sources upstream from Moonlight Beach. Hundreds of notices of violation for urban-runoff pollution infractions were issued to restaurants, gasoline stations, automotive repair shops, and other businesses.

BMPs were implemented throughout the watershed. Structural BMPs include requirements for washing contaminated facilities, detention basins and filters for new development, and drainage facilities. Nonstructural BMPs included good-housekeeping practices, scheduled street sweeping, routine storm-drain facility cleaning, and employee training programs.

Key water-quality parameters in the Cottonwood Creek drainage basin improved over two years because of the combined source identification, BMPs, and enforcement measures. Water testing conducted by the city at both the creek and the ocean outlet showed decreases in turbidity, bacteria, and detergents. Yet despite these efforts, high bacteria levels were not reduced.

The city of Encinitas retained PBS&J to develop a preliminary design report for an urban-runoff treatment facility at Moonlight Beach. The $480,000 facility goal was to significantly reduce bacteria levels in Cottonwood Creek runoff, thereby reducing beach postings. Initial consideration was given to diverting dry-season flow to a local wastewater treatment facility. Cost of required pumping, conveyance, and treatment facilities, however, made this option unfeasible.

Disinfection of urban runoff is usually seen in regions where heavy wet-weather flows routinely enter sanitary sewer lines. These combined wet-weather and sanitary overflows endanger public health and receiving waters. In the past, combined sewer sanitary overflows have been disinfected using chlorination, ozonation, and to a lesser degree, ultraviolet (UV) light.

Traditional chlorine disinfection was considered for the Moonlight Beach project. Chlorine gas or liquid sodium hypochloride would have to be stored at the facility site, posing a vulnerability issue with concerns for the potential danger of storing these chemicals. Also, chlorinated water would need dechlorination prior to discharge, requiring storage of additional chemicals. These concerns removed traditional chlorine disinfection from the list of alternatives.

Ozone has been used in the water treatment industry since the late 1800s for disinfection, odor control, and sludge processing, among other applications. Ozone is generated by an electrical discharge through either dry air or pure oxygen. It is typically generated on-site because it quickly decomposes into elemental oxygen. Since ozone gas can be harmful in high concentrations, an ozone destruct chamber must be constructed to remove residual ozone from treated water before discharge to receiving waters.

Ozonation is most effective when applied

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to waters with low total suspended solids, turbidity, and total organic carbon. To ensure these low levels, a coarse screen and conventional sand filtration typically provide pretreatment.

Effluent from an ozone facility can exceed bacteria limits if influent flow rate or organic loads are highly varied. Variable organic loading can be treated with automated control of the ozone dosage rate, based on oxidation-reduction potential and other parameters. These controls can be complicated and difficult to maintain. Also, ozone generators are not well suited to stop and start based on flow, organic loading, or other parameters. To adapt to variable rates or organic loadings, flow equalization or recirculation is often used.

Had ozonation been selected for the Moonlight Beach project, a monitored side stream of minimal flow would have been continuously recirculated and injected with ozone. In addition to pretreatment filtration, ozone generators, and ozone destruct units, a complete disinfection system requires ozone injectors and injector pumps, a closed-loop chiller, an ozone concentrator, oil-free compressors, an air receiver, an ozone contactor, and an ozone separator. Most of the equipment would have had to fit in the required footprint inside an enclosure, with ozone contact and destruct basins located above or below ground. The ozone system would have met the city's acoustical requirements with some attenuation.

Although UV disinfection has been used in water treatment since the early 1900s, little operational data exists for UV disinfection of urban runoff. UV has the advantage of leaving no disinfectant residual in treated water. For the water conditions in Cottonwood Creek, UV system maintenance is limited to periodic cleaning and lamp replacement every nine months to a year.

Because UV disinfection depends on direct exposure of bacteria to light, low turbidity and low suspended solids are required. Compared to similar urbanized watersheds, Cottonwood Creek has relatively low turbidity and suspended solids, making it suitable for UV treatment.

The UV treatment system evaluated for Moonlight Beach required two basket strainers, two sand filters, and two UV disinfection units. The proposed facility would fit within a 9 x 24 footprint and could be placed in a ventilated enclosure. No special acoustical attenuation was required to meet the city's standards. All intake and return facilities are located in a double box culvert (4 x 6) within city right-of-way to an existing street.

A 12-inch removable wooden weir at the upper end of the south box culvert diverts dry-season flow to the north box culvert, where flow is then diverted to the wet-well pump station. A second removable wooden weir creates a pool at the downstream end of the north culvert. A notch cut into the south culvert weir was designated to discharge approximately 15 percent of the flow to the culvert to provide the required bypass. The weirs can be secured in place during operation and removed during wet periods to minimize debris collection.

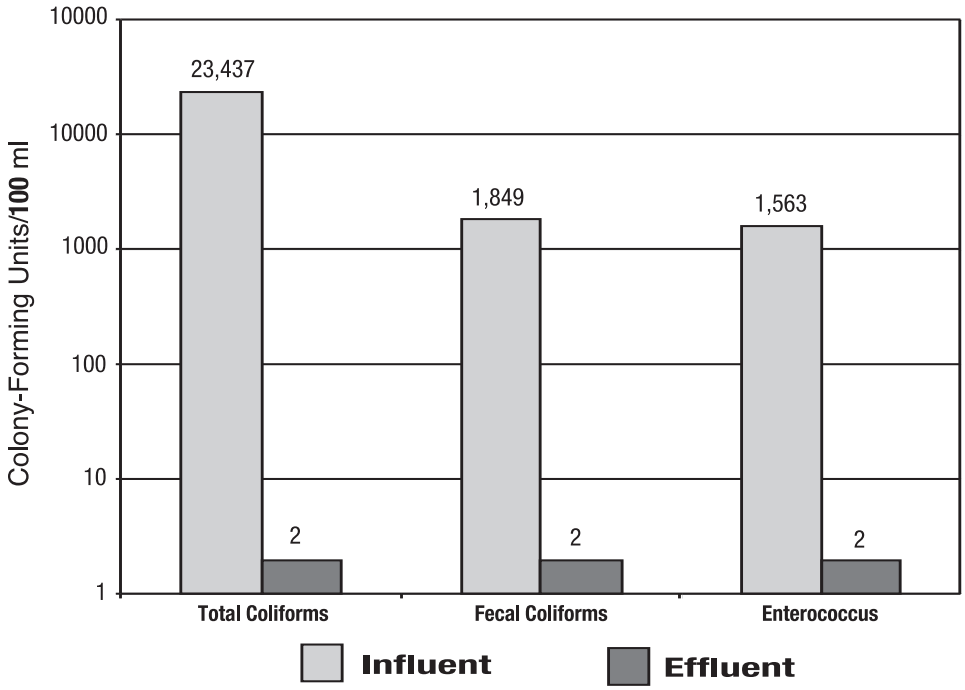
Diverted flow is moved by pumps that handle submersible solids to the treatment facility enclosure. The flow passes through two basket strainers and then flows through two multimedia filters before passing through two UV-light disinfection chambers. To avoid retreatment, the flow is returned downstream of the diversion weir in the south box culvert.

The diversion weirs were sized for a maximum flow of 150 gpm. If higher flows are experienced and the level in the wet well rises above normal operating conditions, an alarm is activated. If the water level in the wet well continues to rise, the system will shut off. Flow contained in the wet well can then return to the creek via the return line. During anticipated heavy rainfall periods, the system is manually shut off and the diversion weirs are removed.

Instrumentation and controls include a flow meter, a turbidity meter, and UV bulb monitors. Automated wipers remove scale buildup in the UV chamber to reduce maintenance and cleaning requirements. Extremely low or high water levels or influent turbidity exceeding 20 NTUs cause the facility to automatically shut down. An alarm is sent via telemetry to the operations center of the San Elijo Joint Power Authority, which monitors and maintains the treatment facility.

The Moonlight Beach facility has been operating since September 2002. Data collected since then found that coliform bacteria were reduced by more than 99.9 percent. Typical turbidity values ranged from 4.75 NTU in the influent to 1.24 NTU in the effluent. Total suspended solids are also significantly reduced, from an average of 14.0 mg/l in the influent to 5.0 mg/l in the effluent. **Figure 1** indicates the influent and effluent sampling data for September through November 2003.

Figure 1. Bacterial Removal at Moonlight Beach



Dana Point, California

Salt Creek and nearby beaches were closed or posted with health advisories due to bacterial level 133 days on average in 2002. To keep its beaches open and safe from harmful bacteria, the city of Dana Point, California, elected to move forward on a $4 million stormwater treatment facility that uses ozone to treat urban runoff. The new facility will filter urban runoff from Salt Creek, and then treat it with ozone in a below-grade concrete basin. The process uses ozone to oxidize contaminates in the water before discharge to the beaches.

The 2,000-square-foot stormwater treatment facility was funded under California's Proposition 40 Clean Beaches Initiative Grant Program. The disinfection facility will be constructed near Salt Creek, adjacent to an existing sewer pump station. When completed, the facility will treat up to 1,000 gallons of stormwater per minute of dry-season runoff from Salt Creek.

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Instrumentation and monitoring will accommodate variations in water quality, and operations staff will be able to adjust treatment levels. Since Salt Creek's typical dry-season flow is about 1,000 gallons per minute, it was not feasible to use a system involving diversion and treatment in a sanitary system. Because of the same safety concerns as at Moonlight Beach, chlorine disinfection was discounted. The final choices were ozone and ultraviolet light systems for stormwater disinfection. Ozone was eventually selected over ultraviolet light, based on levels of iron, hardness, suspended solids, dissolved organics, UV transmission, and other parameters that affect the cost and operation of the proposed facility.

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