FEATURE

P&G's field station: Monitoring detergent safety downstream

The Procter & Gamble Co.'s Environmental Safety Department recently completed the construction of an experimental stream research facility to study the environmental safety of detergent chemicals in rivers and streams. The following article, prepared by James B. Barnum, an aquatic toxicologist with The Procter & Gamble Co., outlines the features and goals of the project.

The Procter & Gamble Co.'s (P&G) state-of-the-science experimental stream research facility near Cincinnati, Ohio, is designed to study the environmental compatibility of consumer product materials entering rivers as part of treated municipal sewage effluent. The one-million-dollar facility, located along the Lower East Fork of the Little Miami River, took four years to complete from concept and design and is currently undergoing several system refinements.

The ultimate goal is to utilize the facility as a research tool for refining environmental safety assessments of detergent ingredients. Although detergents, like many organic materials, are largely removed during sewage treatment, some residual is discharged with treated sewage effluents into streams and rivers.

The experimental stream facility is adjacent to a seven-million-gallons-a-day municipal sewage treatment plant. A 3,500-square-foot stream building of concrete-block construction houses the eight 36-foot long experimental stream channels. An adjoining 550-square-foot trailer provides office and laboratory space. The facility also includes a river water pumping station upstream from the sewage treatment plant discharge, three sewage pumping stations and a 120-square-foot mobile research laboratory.

Although there are a number of stream facilities in the world, the P&G experimental stream research facility is unique because of its many controls that can manipulate various factors. The facility offers environmental realism and experimental control not normally found in traditional laboratory approaches and field investigations. Research investigations include the use of aquatic plant, animal and microbial assemblages representative of communities living in natural rivers and streams, experimentally controlled yet realistic environmental conditions, year-round testing, access to municipal effluents, and replication of environmental conditions for quantitative interpretation.

Classified as a National Scenic Waterway and exceptional warmwater fishery, the Lower East Fork provides a continuous water supply and a source of aquatic organisms for the facility's eight experimental stream channels. Within weeks, many of these organisms settle out and colonize the experimental channels. Sewage, metered into the channels, simulates conditions found below wastewater treatment outfalls. Provisions for adding detergent ingredients into selected channels allow additional environmental safety evaluations of the materials. The Lower East Fork Sewage Treatment Plant, serving approximately 42,000 residents, supplies three types of treated municipal effluents: primary (grit removal only), secondary (grit removal plus biological treatment and settling) and final (grit removal with biological treatment, settling and sand filtration).

In the stream building, electric timers control the artificial lighting to track the natural photoperiod. Delivery rates of river water, sewage and test chemicals are precisely controlled. Water quality parameters (temperature, specific conductance, pH and dissolved oxygen) are monitored continuously for each stream and automatically logged into an electronic spreadsheet.

Design

To meet experimental requirements, a number of attributes were designed into the facility. These include reliability (to sustain long-term investigations), realism (to foster the development of natural

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The experimental research facility contains eight 36-foot long fiber glass and polypropylene stream channels (above) for studying the environmental compatibility of consumer product materials that enter rivers in low concentrations as part of treated municipal sewage effluent. In the photo at right, research associate Dan Davidson monitors growth rates of minnows exposed to various concentrations of effluent.

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stream organism populations and processes), flexibility (to allow evaluation of detergents found under different sewage treatment practices worldwide), control (to reduce the confounding effects of varying environmental conditions) and automation (to continuously monitor environmental conditions that cannot be controlled and to reduce the number of persons needed to operate the facility).

The experimental streams were designed with habitat characteristics of natural streams to establish aquatic communities representative of rivers and streams in general, rather than to produce exact replicas of the Lower East Fork River. The stream channels are constructed of reinforced fiber glass and lined with 3/8-inch black polypropylene for added durability. Each two-foot-wide stream includes three habitat types: a 14-foot-long by two-inch-deep fast-flowing "riffle" reach, followed by a four-foot-long by three-foot-deep slow-moving "pool," and a 14-foot-long by five-inch-deep moderate flowing "run" section. A second pool at the end of the channel results in a riffle—pool—run—pool configuration. Each habitat contains stream bed materials (stones, gravel, sand and silt) appropriate for its flow characteristiacs.

Water depth and velocity are controlled by weirs and by the amount of stream bed material in each habitat section. The channels can be adapted to operate under three different flow regimes: once through, recirculated within a channel or connected in series (up to 288 feet total length). Such provisions increase research design flexibility. Discharge from streams containing sewage and/or test materials is routed back to the wastewater plant for treatment. Water from "river water only" channels is routed directly back to the river.

River water (220 gallons a minute) is continuously supplied to the experimental streams from a 430-gallon head tank in the stream building. Primary-, secondary- or final-treated sewage effluents can be delivered to the streams over a wide range of dilutions from three 280-gallon head tanks connected to the effluent pumping stations. Test materials, such as detergent product ingredients, can be metered into the stream channels from 130-gallon stainless steel tanks located adjacent to each of the stream channels.

Thirty 1000-watt metal arc lamps supply the photo spectrum of natural sunlight and are arranged to emit even light intensities (approximately 500 footcandles) across all eight stream channels. Electronic timers are programmed to track natural twilight and seasonal photoperiod.

Experimental control, monitoring and backup

A chemical metering pump and computer-assisted electronic valves control flow rates of river water, sewage effluents and test materials. Such flow rate control, as well as lighting control, will facilitate the separation of experimental effects from environmental conditions.

Water quality conditions are determined by the river water and sewage effluents pumped to the experimental channels and cannot be controlled. This not only contributes to the environmental realism of the facility, but also necessitates water quality monitoring to provide the best extrapolation of experimental results. Therefore, dissolved oxygen, pH, specific conductance and water temperature are monitored continuously in each stream channel. Data describing the magnitude and duration of any water quality changes are logged at preset intervals, stored in the computer and accessed as an electronic spreadsheet.

Building environmental conditions are controlled and monitored continuously by computer. Automatically activated backup systems, such as a diesel-powered generator and standby river water intake pumps, also are in place to ensure continuous operation during long-term experiments. The extensive control and automation will reduce the number of experimental variables and minimize personnel needed to operate the facility.

Research and operations

A multidisciplinary team of staff scientists, technicians and operation managers has been formed to carry out planned investigations. Areas of research expertise include environmental chemistry and engineering, analytical chemistry, environmental microbiology and aquatic toxicology. Such an integrated approach is necessary to assess various aspects of the physical, chemical and biological fate, chemical exposure and biological effects of detergent materials in this system. Two fulltime personnel will maintain all systems and keep the facility running continuously during the anticipated yearlong experimental program.

The initial scope of the project is divided into three evaluation phases expected to last two to three years. This includes system operational studies as well as physical, chemical and biological evaluations.

After the initial three-phase program, the facility will continue to be used as a tool to help evaluate the environmental safety of certain consumer product ingredients needing an environmental evaluation beyond traditional laboratory approaches.

Phase 1

Phase 1 involves equipment commissioning. The operations team has critically evaluated each major system (river water, sewage and chemical delivery; electrical, lighting and stream channels) and completed necessary refinements to system components. Such thorough assessments and refinements are necessary to decrease the risk of system malfunction after start-up begins. However, these evaluations and refinements have been conducted largely on a system-by-system basis. Thus, a comprehensive equipment commissioning period, with all systems up and running, has been initiated and is expected to last approximately four months.

Phase 2

Prior to launching an aquatic safety program with a detergent ingredient, the experimental streams must be evaluated under the variable conditions encountered during a long-term investigation. Also, research methods must be refined. Although the channels will have some characteristics of natural streams, they are not expected to develop and behave exactly like the biological communities of the Lower East Fork River.

The following evaluations will be initiated during the first year to gain understanding necessary to design future investigations:

• Evaluate and refine all sampling techniques.

• Monitor colonization dynamics of microbes, algae and invertebrates and determine an appropriate colonization period needed before administering the test material.

• Characterize and compare stream community structure (i.e., numbers and types of organisms) and function (e.g., algal respiration, organism growth, organic matter decomposition rates) among the experimental channels to evaluate the natural variability of established stream communities and processes. Natural variability will be used to gauge the appropriate sample replication for statistical analyses in future experiments.

• Determine how the experimental streams compare in structure and function with natural streams below sewage treatment plant outfalls.

• Examine chemical "steady state" in the water column and sediments after the addition of a well-studied detergent compound.

• Evaluate the dynamics of test chemical perturbation and subsequent recovery on stream organisms and processes.

Phase 3

Phase 3 focuses on aquatic safety testing. The findings from Phase 2 will be used to design a safety study of the fate, exposure and effects of another detergent compound. This segment is expected to last approximately one year. Phase 3 will include the following research objectives and subsequent safety tests with detergent materials:

Procter & Gamble Environmental Safety Department section head Dan Woltering (left) and associate director Bill Bishop use blueprints to discuss pipe locations at the P&G field stream facility.

• Evaluate how well long-term (chronic) responses by relatively complex biological communities, comprised of algal and invertebrate species, are predicted by the standard laboratory single-species tests.

• Determine via concentration measurements and predictive methods both the distribution (water and sediments) and the bioavailable fraction of the test chemical and of any identifiable and quantifiable intermediates.

• Characterize the effects of seasonal variations on the distribution of microorganisms and their biodegradative activities in various stream compartments.

• Evaluate acclimation responses of microbial communities and determine the assimilative capacity of stream ecosystems.

• Determine how changes in biodegradative activities alter safety factors in streams.

• Examine the reliability of current aquatic safety factors as judged by population, community and ecosystem level responses at the new research facility.

Procter & Gamble scientists view this undertaking as an exciting opportunity to learn more about the behavior of detergent materials in the environment, while also advancing the field of aquatic risk assessment.