

Monitoring water to keep thousands of visitors safe from intentional or accidental contamination at the Summer Olympics was no small task. But the Beijing Health Ministry found a solution that did the job and will continue to monitor water quality for years to come. **BY DAN KROLL**

TESTING THE WATERS: AN OLYMPIC-SIZE TASK

AS MILLIONS OF PEOPLE around the world were glued to their TV screens last August to watch the drama of the Summer Olympics in Beijing, few of them saw past the spectacle of accomplished athletes, massive venues, and breathtaking entertainment. However, behind the scenes, invisible to attendees and TV viewers, a vast network was in place to ensure security for thousands of athletes and spectators.

Major events, such as the Olympics, are key terrorist targets, as demonstrated at the 1972 Summer Olympics in Munich when Black September terrorists kidnapped and murdered 11 Israeli athletes. Beijing organizers were cognizant of such threats and were determined to cover all possible

avenues of attack. The Chinese government spent \$6.5 billion on security to protect 10,000 athletes, 30,000 journalists, 80 heads of state, and thousands of spectators who gathered in and around the National Stadium (the Bird's Nest), Olympic Village, and surrounding hotels.

Numerous studies have demonstrated that attacking water supplies, especially a distribution system, can be an inexpensive, easy way to cause mass casualties. Depending on a terrorist's choice of contaminants, ingestion of contaminated water, as well as inhalation and skin contact, could cause harm. A water attack on the Olympics would make the sort of headlines that a terrorist organization would be seeking. Beijing organizers were determined to prevent any such attack.

Organizers of the Beijing Olympics were determined to prevent a terrorist attack on water supplies. To provide an unprecedented level of security for the games and continue to enhance daily operations afterward, the Beijing Health Ministry implemented a multiparameter monitoring system.



Contamination Monitoring



China's Beijing Health Ministry, which was responsible for water supply security, wanted to invest in dual-use equipment and methods that would provide an unprecedented level of security for the games and continue to enhance daily operations after the athletes and crowds had gone home. They determined that multiparameter monitoring coupled with intelligent algorithms met their criteria.

MULTIPARAMETER MONITORING

The concept of multiparameter monitoring to detect unusual events in a water supply distribution system has been well demonstrated in studies conducted by the US Environmental Protection Agency, US Army Corps of Engineers, and others. Rather than using individual sensors to detect specific contaminants, the multiparameter approach uses an array of sensors that are commonly available as off-the-shelf water-quality monitors. The system deployed for the Olympics included pH, electrolytic conductivity, turbidity, chlorine residual, and total organic carbon sensors linked together in an intelligent network. This approach has been

deployed extensively in the water supply industry for several years and has performed well in such situations. Because the sensors aren't designed to detect specific contaminants, the system has the ability to warn operators of a wide variety of potential problems, as well as unknown or unforeseen conditions.

Overlaying operation of these basic water-quality sensors is an intelligent algorithm that determines when anomalous conditions exist and attempts to classify the event as to its possible cause. Every 60 sec, the Beijing system measures and analyzes sensor data from five advanced water-quality sensors and calculates a trigger signal, which indicates a deviation from the water-quality baseline. If significant deviations occur, an alarm is activated. When measured in real time, these parameters can show a lot of variability for a given water supply. For such a system to function properly, it must be sensitive to small perturbations yet resilient enough to not be constantly alarming normal fluctuations.

In the Beijing system, the signals from all of the instruments are processed from

five separate parameter measures into a single value in an event monitor computer system that contains the algorithm. The signal then goes through the crucial proprietary baseline estimator. A deviation of the signal from the estimated baseline is then derived. Then a gain matrix is applied that weights the various parameters based on experimental data for a wide variety of probable threat agents. The magnitude of the deviation signal is then compared to a preset threshold level that is set by the operator. If the signal exceeds the threshold, the trigger is activated.

The noise in most deployment scenarios allows the trigger to be set at or around 1. At this level, the system can detect and classify a wide variety of threat agents at concentrations well below what could cause casualties. In most cases, the system can alarm at or around 1-5 percent of the LD-50—the dose that would kill half the people exposed to a given compound.

The deviation vector derived from the trigger algorithm contains significantly more data than what is needed to simply trigger the system. The deviation vector's magnitude relates to concentration and trigger signal, while the deviation vector direction relates to the agent's characteristics. Because this is the case, laboratory agent data can be used to build a threat agent library of deviation vectors. A deviation vector from the water monitor can be compared to agent vectors in the threat agent library to see if there is a match within a tolerance. Each vector results in a vector angle in n-space that indicates the class of agent present. The fact that the direction of the vector is inferential for a given agent type allows the use of an algorithm to classify the cause of a trigger being set off. The agent library is given priority and is searched first. If a match is made, the agent is classified. The fingerprint library contains a wide variety of threat contaminants, including VX (a nerve agent), ricin, arsenic, and herbicides.

By continuously monitoring drinking water at key locations at the games, the early-warning system provided a sense of confidence for security officials that water quality was being guarded effectively.

The unknown alarm rate when the system is tracking real-world data is low. The system is equipped with a recognition algorithm, so, as unknown alarm events occur over time, the system has the ability to store a signature generated during an event. The operator can then access the program to identify the function and associate it with a known cause, such as turning on a pump, switching water sources, etc. The next time the event occurs, it will be recognized and classified appropriately. Over time, as the system is programmed for a given site, the probability of an unknown alarm that hasn't been previously encountered and identified will continue to decrease, eventually approaching zero.

Because of the numerous potential water-quality abnormalities that can be detected, not all of the hypothetical event profiles can be stored in the system's pre-programmed library. Fortunately, an exact match for an unusual water-quality event doesn't have to be in the library. Even if a match isn't found, an alarm condition still exists. This gives the system the unique ability to react to unknown and unanticipated threats. If no match for an event is found, that event's profile is stored in a separate library and can be classified at a later time. If the event recurs, the system will recognize and classify it appropriately. The agent library is provided with the system, and the plant library is programmed on-site. This allows for detection and classification of security-related and operational events and provides the dual-use function the ministry sought.

INSTITUTIONAL INTUITION

Although the Beijing system was designed primarily for water security, its ability to warn of water-quality anomalies of all sorts and to store these profiles for later recall makes it a valuable operational tool. For example, through many years of experience, the best old hands at treatment plants have developed "a sense" for knowing something in the treatment system is amiss. It can be a matter of smell,



color, clarity, sound, or just tingling on the nape of the neck. Operators gain this sixth sense only through extensive experience in a particular facility. Likewise, multiparameter monitoring with interpretive algorithms has the potential to become the sixth sense, capable of learning a distribution system's quirks and having those quirks interpreted by those with extensive experience, giving less-experienced employees the benefit of that institutional intuition without having to absorb it over many years.

With an aging workforce and rapid employee turnover, institutional intuition could evaporate. Beyond obvious security benefits, real-time multiparameter monitoring with algorithms can help utilities circumvent knowledge-base loss and build a base where none previously existed. This approach could help improve system operations, resulting in cost savings and a higher-quality product being delivered to consumers.

CRISIS AVERTED

Fortunately, no water-quality deviations were reported during the Olympics. If

there had been, the monitor would have immediately notified security personnel and signaled automatic samplers to capture real-time water samples at designated monitoring locations. In the event of contamination, the system's classification algorithm would have been an invaluable tool for implementing a rapid, appropriate response.

The success of the 2008 Summer Olympics was a point of immense national pride for China. Unprecedented security measures were taken to deal with potential threats. By continuously monitoring drinking water at key locations at the games, the early-warning system provided a sense of confidence for security officials that water quality was being guarded effectively. In addition, the citizens of Beijing will enjoy the security and operational benefits of continual real-time water-quality monitoring for years to come. The system ensured that when we think about the Beijing games—in the context of water—the only thing that comes to mind will be the records set by Michael Phelps in the Water Cube. 