SUBMERSIBLE PORTABLE IN-SITU AUTOMATED WATER QUALITY BIOMONITORING APPARATUS AND METHOD

I. FIELD OF THE INVENTION

The present invention relates generally to an apparatus and method for monitoring water quality. More particularly, the present invention relates to a submersible apparatus and in-situ method for monitoring water quality using the ventilatory behavior and body movement of aquatic organisms.

II. BACKGROUND OF THE INVENTION

Ventilatory responses are often some of the first prelethal symptoms exhibited by animals to environmental stressors. Continued, abnormal ventilatory behavior, such as rapid, shallow, or erratic breathing, can indicate physiological damage that may be irreversible. Changes in the ventilatory behavior of fish have been shown to be a reliable indicator of accidental toxic spills or "slugs" of pollutants in wastewater and drinking water systems. Accordingly, ventilatory biomonitoring systems can serve as an early indicator of impending damage to aquatic ecosystems and possible harm to humans.

The technological means are readily available to log and display ventilatory signals for subsequent analysis. As a result, there are a considerable number of studies that have examined ventilatory behavior of fish and other aquatic organisms. A large number of substances at lethal levels have been shown to elicit ventilatory responses relatively quickly. For many pollutants, a significant response was often generated in less than one hour of exposure to concentrations approaching the 96-hour LC50 (the concentration at which fifty percent of the organisms expire within 96 hours of exposure). Studies performed using subacutely toxic samples of effluents or individual pollutants (concentrations well below the reported LC50 concentration) often documented responses within one to ten hours of exposure.

Although a variety of organisms have been examined for this purpose, including crayfish, aquatic insect larvae, and bivalves, most research in aquatic ventilatory behavior has used freshwater fish species. This is largely because fish are generally more ecologically "visible" in their importance in aquatic systems and many species (particularly the salmonids and centrarchids) have large opercular flaps that yield relatively clear ventilatory signals for measurement and evaluation.

The ventilatory parameters in fish that have been shown to be affected by toxicity include ventilatory rate (opercular movement over time), depth of ventilation (amplitude), coughing or gill purge rate, and erratic episode frequency due to sudden movement of the organism. Most commonly, changes in just ventilatory rate, as opposed to the other parameters just mentioned, have been used as a bioindicator of toxic conditions. The depth of ventilation and gill purge or cough rate, however, have been reported to be more sensitive indicators of toxicity for some compounds.

Changes in ventilatory rate are often determined by manual examination of the peaks per unit area on a strip-chart recording. Depth of ventilation or signal amplitude is similarly measured from top to bottom of the waveform on the strip chart. Cough rate has been more difficult to determine even with manual examination of a strip chart as several different types of coughs may be present, with their own corresponding characteristic waveform pattern. Also, without the use of simultaneous video techniques, the actual occurrence of a cough is not always clear.

Another important aspect of water quality analysis is the ability to test water from a variety of sources at different locations. This is especially important when the water draining into a body of water comes from different sources. However, the nature and size of water monitoring equipment typically prevents such field testing.

The present inventors previously described a portable, land-based apparatus for automated biomonitoring of water quality in U.S. Ser. No. 10/774,639, filed Feb. 3, 2004, now U.S. Pat. No. 6,988,394, the entire contents of which are hereby incorporated by reference. As described in that application, a system for continuous, real-time comprehensive chemical analysis of drinking water for toxic chemicals is ideal for identifying water-borne threats. An automated fish biomonitoring system enhances detection capabilities for toxic and other chemicals by focusing chemical analyses on water quality changes that might otherwise go undetected. According to that application, the disclosed automated system preferably evaluates three fish behavior parameters, provides rapid notification of abnormal responses, and takes water samples for follow-up chemical analysis.

Today, the biomonitoring systems presently available include a mobile facility and a compact biomonitoring cabinet of the type described in U.S. Pat. No. 6,988,394. The mobile facility is somewhat large, heavy and cumbersome to transport. While the biomonitor cabinet greatly reduces size and weight requirements, it still requires a fixed facility for installation and use.

In order to minimize the equipment and need for a fixed facility, some prior artisans have suggested use of a submersible, or in-situ, monitoring apparatus. As will be appreciated, a submersible or in-situ monitoring apparatus would eliminate the need for pumps, manifolds, temperature controls, motors, etc. that are necessary for sampling, transporting, conditioning and analyzing water with existing prior art biomonitoring systems. An in-situ application would be particularly advantageous with fish farms or the like where real time monitoring of conditions that pose a threat to fish could be detected almost immediately so corrective action could be taken to avoid loss of an entire crop of fish. However, the construction of a submersible or in-situ monitoring device has proven problematic. For reasons not easily explained, there exists a physical phenomenon whereby signals generated by fish in a submersed monitoring chamber are incapable of being received in a quality sufficient for biomonitoring. Most prior artisans agree that pursuit of a submersible monitoring chamber is a lost cause due to this inability to receive suitable signals from fish in a submersed exposure chamber.

Accordingly, there exists a long-felt, yet unresolved need in the art for a submersible biomonitoring chamber. The present invention meets this need by the provision of novel equipment and methods of monitoring water quality through deployment of fish monitoring chambers directly in the body of water to be monitored. This submersible system not only overcomes the need for a fixed facility, but also fulfills the long-felt need in the art for in-situ water quality biomonitoring.

III. SUMMARY OF THE INVENTION

The present invention overcomes the practical problems described above and provides additional advantages as well. The present invention is based, in part, on the discovery that the use of specifically-proportioned biomonitoring chambers