

Tools for Addressing Low-Level Chronic Toxicity in Wastewater Treatment Plant Effluents

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Despite continued controversy between science and policy over the use of toxicity testing as a National Pollutant Discharge Elimination System (NPDES) enforcement tool, permits with whole effluent toxicity (WET) requirements are commonplace in many states. As enforcement activities associated with WET permit violations increase nationwide, the need to produce a higher-quality effluent continues to increase.

Established designs and practices that served the needs of the wastewater community for decades are no longer adequate and have forced continued improvement of industry standards in wastewater treatment. Along with this requirement for improved wastewater treatment technology is the need for robust techniques in identifying toxicants—particularly those toxicants that cause impairment to reproduction, growth or fecundity (egg development) of the aquatic toxicity test organisms. This article will discuss various challenges associated with this issue and will present one particularly effective method in dealing with low level chronic toxicity.

A Brief History

One of the earliest efforts to develop toxicity identification and reduction evaluation (TIE/TRE) procedures took place in the late 1980s. The U.S. Environmental Protection Agency (EPA) developed methods for characterizing effluent toxicity (Phase I), identifying specific components of toxicity (Phase II), and confirming the toxicants (Phase III). These procedures were published in several documents in 1988 and 1989 and concentrated on identifying acute toxicity or toxicity that caused lethality in a particular period of time, usually 48 hours.

These manuals included methods for identifying toxic metals, volatile compounds that can be oxidized, chemical oxidants, and nonpolar organic compounds. There are detailed methods for analytical identification with gas chromatography/mass spectrophotometry (GC/MC) and high-pressure liquid chromatography (HPLC). The efficacy of

these methods has been proven for toxicants in concentrations high enough to cause acute responses in the test organisms.

In the mid and late 1980s, most facilities with NPDES testing requirements were performing acute toxicity tests, and many found it very difficult to pass them consistently. The problem dramatically worsened when chronic toxicity test procedures were promulgated. Toxicants such as total residual chlorine, ammonia, and wastewater treatment additives were commonplace and relatively easy to identify using EPA TIE procedures.

New and improved methods for toxicity identification, including those for chronically toxic effluents, were developed over the next decade, and EPA methods were published (the most recent in 2001) that provided clarifications for toxicity identification and reduction studies. The 2001 document included an acknowledgement that TIE results may be inconclusive in rare occasions and recommended that regulatory agencies consider the issue of effluent complexity in enforcement actions.

The Scope of the Problem

The process of conducting a TIE can be drawn out and quite complex. Despite great strides made by the EPA, university research, and private laboratories in the development of TIE/TRE methods, there remains the challenge of identifying the source of toxicants that have a slight or marginal effect on effluent chronic toxicity.

The debate as to what constitutes “slight impairment” to *Ceriodaphnia* reproduction or *Mysid* Shrimp fecundity, considering the inherent variability of these species and test

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procedures, is beyond the scope of this article. For the sake of this discussion, low-level chronic toxicity will be defined as toxicity that causes marginal impairment (25 to 40 percent) at the effluent concentration of concern.

Depending on the state or federal regulatory authority, the effluent concentration of concern will vary. It may be 100-percent effluent, the effluent concentration at low stream-flow conditions, or some other concentration selected by the NPDES permitting authority.

It is important to keep in mind that toxicants that slightly reduce the reproduction or growth of the toxicity test organisms are often in the parts-per-billion concentration range. At these extremely low levels, GC/MS and HPLC analyses have limitations when identifying unknown compounds, despite the library search capabilities of these instruments. A laboratory may vigilantly work on toxicity identification and think that the toxicity source has been identified, only to discover that the problem is much bigger than initially perceived, which can cost a facility valuable time and financial resources.

Factors that affect the success of a TIE include the experience of laboratory personnel, time and financial constraints, and the complexity of the effluent toxicity. Although laboratory personnel experience is paramount to the success of a TIE/TRE program, the complexity of the effluent toxicity is an often underestimated consideration.

There are several contributors to effluent toxicity complexity (Figure 1) that increase the difficulty level of the project. Probably the most relevant to this discussion are the magnitude and frequency of toxicity present. The causes of toxicity for an effluent that is always very toxic are far less difficult to reconcile than the

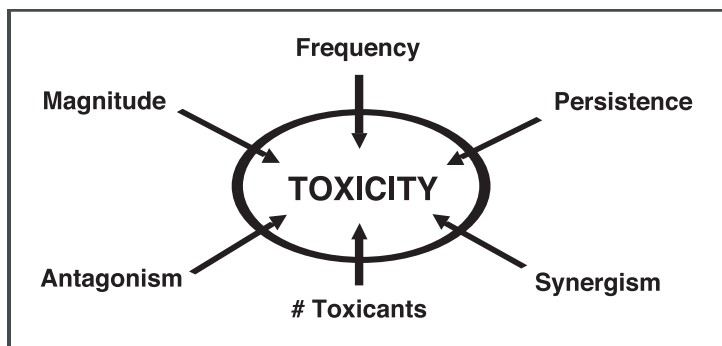


Figure 1: Effluent Toxicity Complexity Factors

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causes of toxicity for an effluent that is less toxic, less often.

Some Useful Tools

There are a number of steps that can be taken to address chronic toxicity in cases where the EPA Phase I, II, and III procedures prove ineffective—including more focused HPLC fractionations using solvents with varying polarity, molecular sieving, and numerous tests to determine ionic imbalances.

Ionic imbalances produced by textile or oil refining processes that result in high TDS can be readily identified using spiking procedures. Processes that produce effluents with low ionic strength, such as groundwater remediation samples, can be more difficult to reconcile, but procedures for reconstructing “mock” effluent samples are often helpful in the identification process. In some cases, the cause of chronic toxicity may be so difficult to determine that the facility opts to use a material such as granular or powdered activated carbon to remove all sources of toxicity rather than identify them.

Refractory Toxicity Assessment Procedures

For a municipal wastewater treatment facility, an additional layer of complexity exists if the facility has numerous industrial users. Over the past decade, municipal facilities have been very successful in eliminating toxicity associated with the treatment process, such as chlorination and de-chlorination, inadequate de-nitrification, polymer addition, and so forth.

Facilities that have ruled out sources of effluent toxicity associated with wastewater treatment are more likely to encounter toxicity that originates from one or more industrial sources. For this reason, facilities have found it beneficial to develop comprehensive toxicity management programs that include the requirement for all or selected industrial users to perform refractory toxicity assessment (RTA) testing.

The general RTA procedure described by the EPA (1999) can be adapted to identify and monitor sources of toxicity entering a publicly owned treatment works (POTW). Trunkline or industrial user samples are treated in a bench-scale simulation of the wastewater treatment plant, with the resulting reactor effluents tested for chronic toxic-

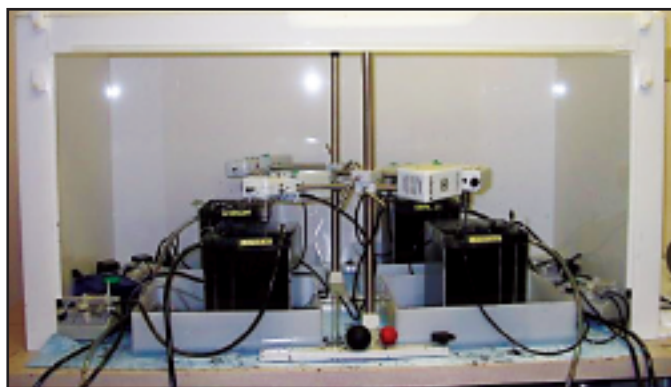


Figure 2: Flow-Through Reactor System

city to the NPDES permit test species.

RTA testing utilizes two general types of simulations: a control simulation treating plant influent without the industry of concern, providing baseline data on the treatment provided by the plant; and a test simulation treating an industrial user’s wastewater spiked into the plant’s influent. Reactors can be run as batch or continuous flow-through systems as pictured in Figure 2.

A facility can adjust the sensitivity of the RTA study by increasing the concentrations of industrial wastewater loading into the reactor system or by performing several reactor loading scenarios as described in Figure 3.

Toxicity observed in the simulation effluents is referred to as “refractory” or toxicity that would be expected to pass through the wastewater treatment plant and contribute to unacceptable effluent toxicity. Evidence of refractory toxicity would be indicated by significantly greater toxicity in the spiked simulation effluent relative to the control.

During the treatment simulation, the bioreactor mixed liquors are aerated for a period of time corresponding to the hydraulic retention time (HRT) of the facility’s activated sludge process. During testing, chemical oxy-

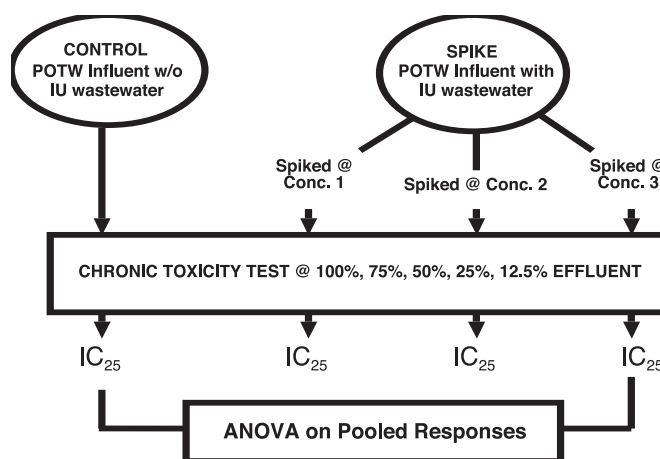


Figure 3: Typical RTA Protocol Design

gen demand (COD), ammonia-nitrogen ($\text{NH}_3\text{-N}$) and mixed liquor suspended solids (MLSS) measurements are taken to confirm that the treatment performance of the RTA simulations are similar to the wastewater treatment plant performance. Any number of variations can be made to the study design to fit the need of the facility.

For facilities in which the effluent persistence is known, one variation of the program is to require each (or selective) industrial users to collect samples of wastewater each time

the POTW collects a sample for the NPDES toxicity test. If the POTW fails the compliance test, the facility requires all or some of the industrial users to perform the refractory toxicity test. If the POTW passes the NPDES toxicity test, industrial users discard the samples. In this way, the POTW substantially increases the likelihood of identifying the sources of toxicity for a particular testing event.

This is a real crowd pleaser with the regulatory agencies because it expands ownership of effluent quality to the industrial community. From the POTW perspective, an added benefit is the ability to share the cost of testing with the industrial users.

Educating the Industrial Community

Gathering as much information as possible on the nature of the chemicals entering the wastewater treatment plant is important. Educating the industrial community about toxicity is another tool for improving compliance.

Most indirect dischargers have no concept of the challenges involved in meeting toxicity requirements consistently, and they will be valuable partners in solving the problem once they are notified. Understanding that whole effluent toxicity is as much a result of non-biodegradable toxicants passing through as concentrations entering a wastewater treatment plant is paramount to a successful toxicity management program.

References

- USEPA, 1999a. Toxicity Reduction Evaluation Guidance For Municipal Wastewater Treatment Plants. EPA-833B-99-002. Office of Water, Washington, DC.
- USEPA, 2001. Clarifications Regarding Toxicity Reduction and Identification Evaluations in the National Pollutant Discharge Elimination System Program. ◊